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A Pocket Companion for

The Uniform Design

of

Reinforced Concrete

by

Louis F. Brayton
Consulting Engineer

Minneapolis
1906

640

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Preface

Reinforced concrete has ceased to be an experiment in the hands of the specialist. The strength of the various members required in the composition of a structure, can be as safely calculated in reinforced concrete as they can be in wood or steel. The principal difficulty at the present time lies in the fact that the specialists doing this class of work are largely in the employ of companies who are exploiting some particular feature in the line of reinforcement.

Architects and engineers have grown into the habit of specifying that the contractor shall furnish the designs for the reinforced portions of the work under consideration. General contractors in turn have been obliged to go to subcontractors who make a specialty of this line of work to get the designs. The result has been that no two competitors base their bids upon the same design. The one accepted may be unnecessarily expensive because of the patented features in the reinforcement used, or it may be unsafe because of the insufficiency in the materials, or an inefficiency in the design.

Brayton Standards is a compilation of information acquired from actual experience, coupled with the necessary theory. The methods of construction shown are not merely theoretical, but have been put into practice and found highly efficient and economical. No patented bars are used, although there could be no objection to them if placed in equivalent quantities, and in the forms shown. Plain, round rods are the cheapest form of reinforcement, as they may be bought in any market and are not subject to the prices quoted upon bars of special design. They will accomplish every duty required of them if they are placed in the proper form, as indicated in the accompanying details.

Where some form of distorted bar is considered necessary to aid the adhesion of the concrete, plain twisted square bars will serve every purpose. These may be obtained from many sources without extra cost, except that added for the labor of twisting.

The primary object in placing these tables and details in such form as to be available for the use of all, is to enable arthitects and engineers who have not made a specialty of this class of work, to show the complete drawings required to properly illustrate a structure in reinforced concrete, so that all contractors bidding upon the work will bid on a uniform basis, and upon a design which is entirely satisfactory to all those concerned.

Brayton Standards are conservative, and as accurate as is consistent with this class of work. It is hoped that the use of them will render the design of reinforced concrete as easy for architects, engineers and builders as is the design of a steel structure at the present time.

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Dedication to the Public.

Several patents have been issued to me for Reinforced Concrete Construction involving principles utilized in the Uniform Design set forth in this book; and various additional applications for patents have been filed by me relating to such structures. Wishing to render available to the public this design for Reinforced Concrete Construction, I have executed an instrument dedicating and giving to the public all my rights under the said patents and under any additional patents which may be granted on any of the said applications. Hereinbelow is printed a copy of the said instrument of dedication, identifying the said patents and applications

Dedication to the Public.

WHEREAS certain United States and Canadian patents have hitherto been issued to me relating to Reinforced Concrete Construction; and whereas certain applications for United States Letters Patents have hitherto been filed by me relating to such construction; and whereas I am desirous of rendering available to the public all of the said devices;

NOW, THEREFORE TO ALL WHOM IT MAY CONCERN: Be it known, I hereby dedicate and give to the public all my rights under each and all of the hereinbelow identified patents and all rights which may be invested in me under any additional patents which may he granted on the hereinbelow applications, or any thereof.

The said patents and applications above referred to are identified as follows:

United States Patents No. 786,622 issued to me of date April, 4 1905 and No. 791,046 issued to me of date June 6, 1905.

Canadian patents No's 94,883; 94,884; 94,885 and 94,886, all issued to me of date August 29, 1905. Canadian patents No. 92,906 issued to me of date May 22, 1905; No. 92,669 issued to me of date April 18, 1905; and No. 94,875 issued to me of date August 29, 1905.

Applications for United States Letters Patent S, N. 220,745, filed by me August 15, 1904; S. N. 221,592, filed August 22, 1904; S. N. 221,593, filed August 22, 1904; S. N. 222,056 filed August 25, 1904; and S. N. 245,816 filed February 16, 1905.

Sigend at Minneapolis, Minnesota, this 25th day of April, 1906.

Louis F. Brayton

In the presence of
James F. Williamson,
Frank D. Merchant
Patent Attorneys,
925-933 Guaranty Loan Building,
Minneapolis, Minnesota.

STATE OF MINNESOTA, ss.
COUNTY OF HENNEPIN.

On this 25th day of April, 1906, before me, a Notary Public in and for the County aforesaid, personally appeared Louis F. Brayton, to me known to be the identical person who executed the foregoing instrument, and acknowledged that he executed the same as his own free act and deed.

Stephen Mahoney, Notary Public,
Hennepin County, Minnesota.
SEAL. My Commission expires February 7, 1913.

THE UNIFORM DESIGN

OF

REINFORCED CONCRETE

REINFORCED CONCRETE.

Principles of Design

In the planning of a structure in reinforced concrete, as well as in other materials, there are two questions of utmost importance: The question of capacity to preform the duties imposed upon the structure, and the question of cost. The two are so closely related that each must be kept continually in mind when the other is under consideration.

The tables contained herein, are prepared in such a way as to be simple in their use, but it is left to the designer to use them to the best advantage from the standpoint of economy.

Particular attention is called to the use of continuous construction in slabs, and especially when it is used in the form of "two-way" reinforcement, supported upon the four sides of the panel. The maximum economy is here attained. A word of caution, however, may prevent an error in the calculation of oblong panels of the "two-way" type.. The method by which these panels are calculated is explained on page 12. Another frequent source of error is the neglect of the *end span*, where continuous reinforcement is used. This span should be calculated by a different formula, as noted in connection with the illustrations on page 21. See also the discussion on page 20.

The question of economy of a structure may be largely influenced by the designer, if proper attention is paid to the forms which will be required in construction. For instance, consider that a nine-story warehouse may be under construction: The first, second and third floors may have a capacity of 500 pounds per square foot; the fourth and fifth floors a capacity of 300 pounds per square foot, and the remaining floors 200 pounds per square foot, except the roof, which need be calculated for only 50 pounds liveload. If one were to design this building without particular reference to the forms, he might assume certain sized beams for the first three floors, then, as the capacity reduces in the floors above, the beams might be correspondingly reduced in their dimensions, as well as in the rods used for tension purposes. The roof might have beams of a very small size compared with those used in the floors.

From the standpoint of economy, the sizes of beams should be maintained the same throughout the building, if at all possible, for the reason that it will be far more economical to buy enough lumber for only about one third the floors, manufacture the beams into permanent forms, and use them three times during the construction of the building, than to rebuild the forms for so many different sizes of beams. With this arrangement, as the lower floors become sufficiently set to become self supporting, the forms may be removed and used in the upper stories. If the beams in the upper stories are of smaller dimensions than they are below, the labor of remodeling forms will cost far more than the extra concrete would if the beams were made of the same dimensions as used under the heavier capacities. Even the roof with its extremely light load may be more economical if the large sized beams are used.

If for any reason it is necessary to change the sizes of the beams, then the dimensions should be arranged in such a way that the forms can be conveniently changed without ripping the lumber. This might be attained by making an even four-inch change in depth, so that if the forms were built using a 2x4 in the side, it could be removed to give the shallower depth beam.

The same principal occurs in the construction of columns. It is economy to use the same sized columns from the basement to roof, or at least, not change the size of columns more than once, throughout the height of the column stack. If the column is changed in size one or two inches at every story, it will mean not only remodeling all column forms, but the splicing out of beam forms in order to make them properly fit the new dimensions.

The Theory

For those who wish to know the basis upon which these tables are calculated, and for use under conditions which may arise outside of those covered, the accompanying diagram and explanation are given.

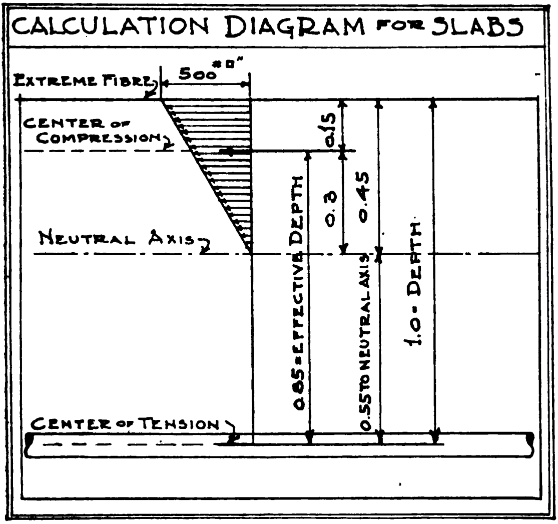
Where such points as the neutral axis, center of compression, etc., are assumed, suffice it to say that the assumptions have been based upon tests from numerous sources, and that although the theory may be impirical in some ways, it certainly is not in error more than two or three per cent. In consideration of the materials used and the high factors of safety required, closer calculation than this would amounts to hair splitting.

Points in the following discussion are graphically shown on page 7.

It is assumed the compression area is a triangle with its center of gravity at two-thirds of the height. The neutral axis is located at a depth of 0.45 of the distance from the extreme compression fibre to the center of tension. Thus the effective depth which is the distance between the centers of tension and compression, is equal to 0.85 of the distance of the center of tension from the extreme compression fibre. The moment of resistance is equal to the effective depth multiplied by the tension. The exact location of the 'neutral axis is not of great importance for it can be seen that if it were lowered, increasing the compression triangle, the effective depth would also be decreased and the moment of resistance consequently influenced in a lesser degree.

Considering a beam 12 inches wide and 1 inch deep from the extreme compression fibre to the centre of gravity of the steel, the compression area is found to be 2.7 square inches, with a total pressure of 1350 pounds. The effective depth is 0.85 of the total depth, and the tension required in steel is 1350 pounds, all as shown by the diagram.

The moment of resistance in foot pounds is equal to the stress in the steel multiplied by the effective depth in feet, giving a result of 95.62 foot pounds.



This diagram is designed with the idea that the extreme fibre will attain its full safe capacity of 500 pounds per square inch, which is a factor of safety of at least four on the concrete when the steel is stressed to one half its elastic limit, giving the regulation factor of safety of two required for steel in combination with concrete.

If the bending moment is such as not to require the full development of the concrete in compression the conditions will change only in the amount of tension supplied, and the pressure on the concrete or the location of the neutral axis need not be considered. If only 56.6 foot pounds of resistance were required, then only 800 pounds tension would be needed in the steel and the area would be reduced by one-half.

For the properties of *any* beam developing the full capacity of the concrete, the process of calculation is merely by comparison with the beam 1 inch deep as already explained. Thus, where *the depth* means the distance from the extreme compression fibre to the center of tension in inches, the total capacity in pounds of the compression flange of a rectangular beam is 1350 times the depth. The tension being always equal to the compression in a beam, *the maximum tension* in pounds *which a beam can takc is also equal to 1350 times the depth in inches.* Steel supplying tension in addition to this amount would be wasted.

Since the tension in a beam and the effective depth, or the moment arm, are each directly proportional to *the depth*, the moment of resistance, which is the product of the two, is proportional to the *square* of the depth. Hence, by comparison with the beam one inch in depth, *the moment of resistance of any beam in foot pounds is equal to 95.62 times the square of the depth in inches.*

Example: (1). What is the moment of resistance of a reinforced concrete beam 12 inches wide by 20 inches deep. (2). What is the area of steel required, the steel having an elastic limit of 32,000 pounds per square inch. (3). What area of steel would be required to give a moment of resistance of 34,000 foot pounds.

Answer:

(1) Moment of resistance $=95.62\times20^2=38248$ foot pounds

(2) Area of Steel $=\frac{1350\times20}{16000}=1.69$ square inches.

(3) Area of Steel $=\frac{34000\times12}{0.85\times20\times16000}=1.5$ inches.

The Location of the Steel.

A reinforced concrete beam or floor slab is nothing less than a truss, and it may be treated in exactly the same manner. A truss may have its tension web members on the vertical or diagonal. It is equally good either way, but the efficiency of these members is absolutely limited by the strength of their connections at either the bottom or the top chord.

The same thing is true of the reinforced concrete truss. It should be laid out with an effective depth of 0.85 of the total depth, and calculated in the same manner as a truss of any ordinary type. The concrete will fulfill the requirements of compression in the top chord and web, and steel should be placed to take the tension in the lower chord and web. Steel web members, as in the ordinary truss, should be proportioned to the stresses in them and they should be provided with a method of connection to each chord of sufficient strength to develop these stresses.

A beam or girder is usually used in connection with the floor slab, and the two are so thoroughly bonded together that they act as one in the form of a tee-section. The slab, like the compression flange of an I-beam, assists in providing the compression strains in the beam. There is a source for argument as to how far out into the slab it may be considered that the tee-section extends, the slab acting with and as a part of the compression area of the beam; but it is perfectly logical to assume that this slab does take some of the compression of the beam, the same as the flange plates in a plate girder are made to resist the compression stresses by means of their connection through the flange angles and rivets to the web.

In ordinary construction, where the floor slab runs as thick as 5 or 6 inches and the tension stresses of the beam are not exceptionally large, there is not much question but that the slab will supply all of the compression required, without assuming its width to be more than three or four feet.

In thin slabs, however, or where the beam is of such a high capacity as to require a great amount of steel in the tension flange, the slab may be called upon to supply an excessive amount of compression. In this case the test of how wide a portion of the slab may be considered as acting in compression with the beam, should be the shearing value of the slab both vertically and horizontally where it connects with the beam. The principal is the same as the calculation of rivet spacing in the flange of a plate girder. If the arrangement of steel is provided as shown in the standards, the shear along the plane of the lower side of the slab is amply provided for within the steel members as they pass from the lower flange of the beam, up into the slab and over the point of support.

In cases where the slab is so thin as not to be considered of value in providing compression, steel reinforcement in the form of rods imbedded in the compression chord of the beam should be provided in sufficient quantity to give it the required strength and reduce the fibre strain in the concrete to a maximum of 500 pounds to the square inch. In placing these rods in the compression chord of the beam, care should be taken that they are so located as to be thoroughly bonded to the rest of the beam by means of their intermingling with the shear loops.

Distribution of Load in a Rectangular Panel.

From the standpoint of economy it is advisable always to reinforce a concrete slab in two directions. By this arrangement of the steel, whether it is simple or continuous, the load is carried in two directions and is supported on the four sides of the panel by means of the surrounding beams or walls.

In order to calculate the proportion of the load, both the live and the dead, which is carried in each of the two directions, it is necessary to calculate the strains caused in the oblong panel under the deflection obtained. It will be readily seen that under a given deflection a much greater strain will be caused in the direction of the short span than in the direction of the long span, for the distortion is proportionally greater.

It is unnecessary to explain the details of the calculations to arrive at the accompanying table given on page 14. The results are in the most convenient form.

The first column of the table gives the ratio of the length to the breadth, the second column in the table gives the proportion of the load per square foot which is carried by the short span, and the third column gives the proportion of the load which is carried by the long span.

It will be seen that in a panel perfectly square, where the length is equal to the breadth, the ratio is one, and that an equal amount of the load is carried in each direction. In this case the designer would assume the dead and live load per square foot, divide this by two, and calculate the thickness of slab, and the amount of reinforcement required to carry this load on the span given. The total reinforcement required for the slab would be equal to double the amount required by this calculation, as it would be used in both directions.

In case the ratio of the length to the breath should be 1.2, the table shows that 0.675 of the load is carried on the short span and 0.325 of it is carried on the long span. The method of calculation in this case would be to consider 0.675 of the total load per spuare foot as being carried on the short span, and the thickness of slab and reinforcement would be determined by these assumptions. The thickness of the slab being thus determined, it remains only to calculate the reinforcement required in the long direction of the panel. This is done by placing sufficient steel in the slab already calculated to give a moment of resistance equal to the bending moment caused by 0.325 of the total load being carried on the long span.

Particular attention is called to the fact that in all formulae given in connection with the diagrams, W represents that portion of the total dead and live loads per square foot, which is carried in the direction of the span under consideration.

It will be readily seen that a panel very oblong is not an economical proposition, and the designer should make every effort to keep the rectangles as near square as possible.

Distribution of Load in a Rectangular Panel.

$\frac{\text{Length}}{\text{Breadth}}$	Proportion of Total Load per Square Foot which is Carried by the Short Span	Proportion of Total Load per Square Foot which is Carried by the Long Span
1.0	0.500	0.500
1.1	0.595	0.405
1.2	0.675	0.325
1.3	0.740	0.260
1.4	0.790	0.210
1.5	0.835	0.165
1.6	0.865	0.135
1.7	0.895	0.105
1.8	0.915	0.085
1.9	0.930	0.070
2.0	0.940	0.060

Slab Reinforcement.

These standards illustrate the different methods of placing round rod reinforcement within slabs as required to fulfil the various conditions. In cases where slabs bear upon walls, it may be impossible to get continuous construction, and the simple span, "one way" reinforcement may be the one type available.

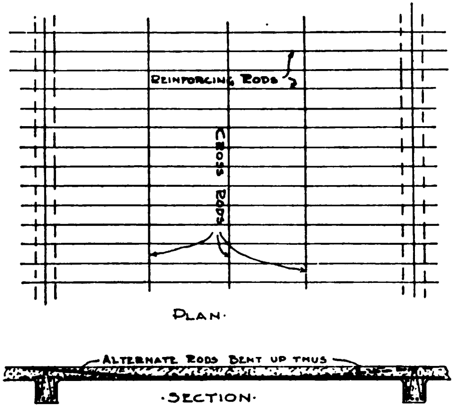
The designer should always, if possible, manage to insert beams so as to divide up the slab into rectangular panels as near square as possible, and to place the steel in two directions. This "two-way" reinforcement has an economy in it, whether it be of the simple or continuous type, for, because of the panel effect, it is permissible to calculate the bending moment more economically.

In slabs, reinforcement should be placed so as to provide for the shear. This is especially true where long spans are used. Shear is amply provided for when the rods are placed as shown in the accompanying details.

Attention is called to the method of placing *similar* rods in continuous construction, so as to provide a truss form, within the concrete, the truss being accomplished by means of the alternate arrangement of the rods.

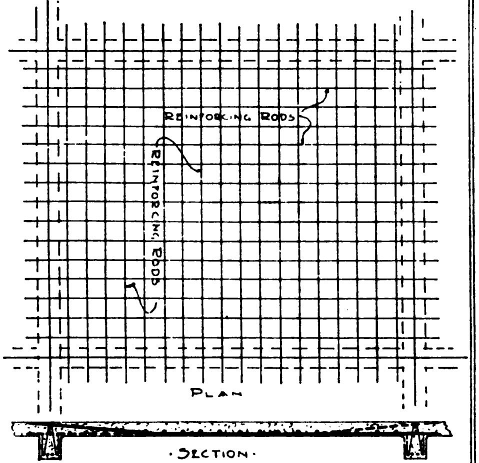
Simple Span Reinforcement.

·SIMPLE SPAN·ONE WAY REINFORCEMENT·



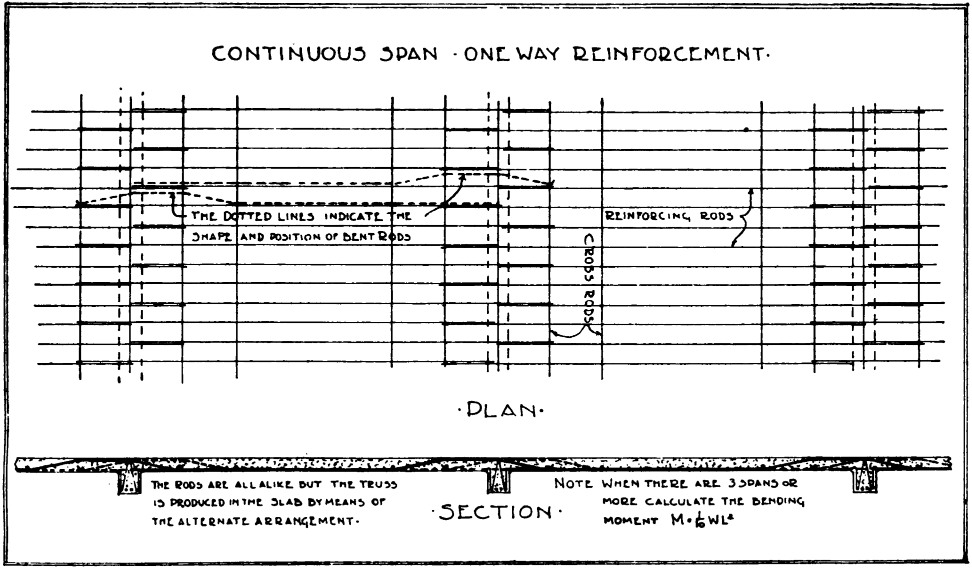
NOTE· FOR THIS TYPE OF REINFORCEMENT CALCULATE THE BENDING MOMENT - $M = \frac{1}{8} WL^2$

·SIMPLE SPAN TWO WAY REINFORCEMENT·

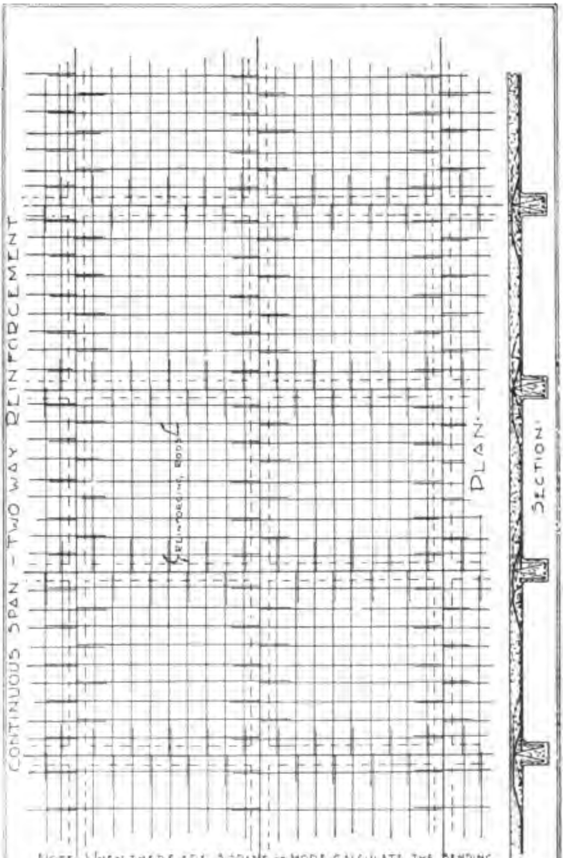


NOTE · FOR THIS TYPE OF REINFORCEMENT CALCULATE THE BENDING MOMENT $M = \frac{1}{10} WL^2$ IN EACH DIRECTION·

Continuous Reinforcement.


CONTINUOUS SPAN · ONE WAY REINFORCEMENT·
THE DOTTED LINES INDICATE THE SHAPE AND POSITION OF BENT RODS
REINFORCING RODS
CROSS RODS
·PLAN·
THE RODS ARE ALL ALIKE BUT THE TRUSS IS PRODUCED IN THE SLAB BY MEANS OF THE ALTERNATE ARRANGEMENT·
·SECTION·
NOTE WHEN THERE ARE 3 SPANS OR MORE CALCULATE THE BENDING MOMENT $M \cdot \frac{1}{10} WL^2$

Continuous Reinforcement.



NOTE—WHEN THERE ARE 3 SPANS OR MORE CALCULATE THE BENDING MOMENT $M = \frac{1}{12} WL^2$ IN EACH DIRECTION. 'W' HERE MEANS THAT PORTION OF THE TOTAL DEAD + LIVE LOAD PER SQUARE FOOT WHICH IS CARRIED IN THE DIRECTION OF THE REINFORCEMENT BEING CALCULATED. SEE EXPLANATION OF LOADS IN RECTANGULAR PANELS.

Bending Moment in Slabs for Various Types of Reinforcement.

On page 21 are illustrated two general styles of reinforcement, the simple and the continuous. The simple span under some conditions may be combined with the continuous construction, as shown between the other two types. Either the simple span, or the continuous span, or the combination single and continuous span may be used in two directions in the same panel. Thus, in all, there will be six types of reinforcement, and under every type a different formula is used for the calculation of the bending moment.

For the simple span one-way type of reinforcement, M is equal to ⅛ WL^2 where M equals the bending moment in foot pounds, W equals the dead plus the live loads per square foot, and L equals the span in feet.

When this type of reinforcement is used in two directions the strength of the slab is very materially increased because of its being supported on the four sides, and it will be *more than twice* as strong, as if it were supported on two sides. Under these conditions the bending moment is considered equal to 1-10 WL^2 in each direction, W being considered that portion of the total dead and live loads per square foot (see the table on page 14) carried on the span under consideration.

For the combination of the simple and the continuous type one-way reinforcement, M is equal to 1-9 WL^2, and for this same reinforcement of the two-way type M may be considered equal to 1-11 WL^2 in each direction, W and L having the values as stated above.

For the continuous one-way type of reinforcement, M is to be calculated as equal to 1-10 WL^2, and where the two-way type continuous reinforcement is used M may be considered to be equal to 1-12 WL^2 in each direction, W and L being subject to the conditions stated above.

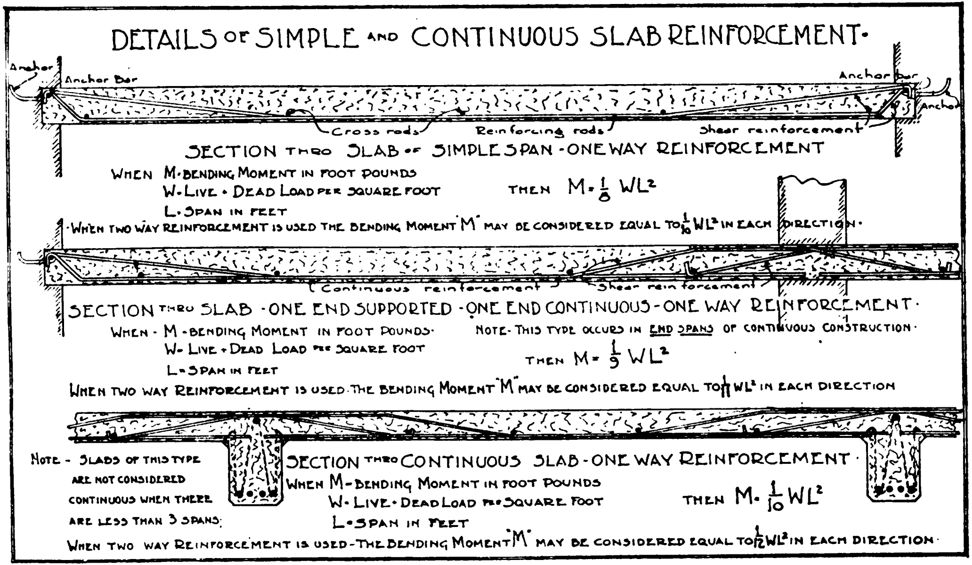
All tables here given, which involve the question of bending moment, are calculated for the simple span of the one-way type of reinforcement, where the bending moment $M = \frac{1}{8} WL^2$. In order to use these tables with other types of reinforcement the totol dead and live load per square foot should be reduced to an *equivalent* load per square foot, by multiplying the load under consideration by a coefficient corresponding to the type of reinforcement adopted. The results given, by using this equivalent load in the tables, will be correct for the corresponding type of reinforcement.

The coefficients for the various types are as follows:

Coefficient for simple one-way type	=	1.000
,, ,, combination simple and continuous one-way type	=	0.888
,, ,, continuous one-way type	=	0.800
,, ,, simple two-way type	=	0.800
,, ,, combination simple and continuous two-way type	=	0.727
,, ,, continuous two-way type	=	0.666

In continuous construction the designer will save himself trouble and make the construction more uniform, if he will make the end spans equal to 0.95 of the interior spans. It will be found by simple calculation that if the exterior span is 0.95 in length of the interior span, the formula for the bending moment equal to 1-9 WL^2 for end spans, will give practically the same bending moment, as will the formula $M = 1\text{-}10 WL^2$ for the interior spans, and the construction may remain uniform in thickness, and in size and spacing of rods. The same conditions hold true for the continuous types.

Details of Slab Reinforcements.



SECTION THRO SLAB OF SIMPLE SPAN - ONE WAY REINFORCEMENT

WHEN M·BENDING MOMENT IN FOOT POUNDS
W·LIVE + DEAD LOAD PER SQUARE FOOT
L·SPAN IN FEET

THEN $M = \frac{1}{8} WL^2$

·WHEN TWO WAY REINFORCEMENT IS USED THE BENDING MOMENT "M" MAY BE CONSIDERED EQUAL TO $\frac{1}{10} WL^2$ IN EACH DIRECTION·

SECTION THRO SLAB - ONE END SUPPORTED - ONE END CONTINUOUS - ONE WAY REINFORCEMENT·

WHEN - M - BENDING MOMENT IN FOOT POUNDS·
W - LIVE + DEAD LOAD PER SQUARE FOOT
L = SPAN IN FEET

NOTE - THIS TYPE OCCURS IN END SPANS OF CONTINUOUS CONSTRUCTION·

THEN $M = \frac{1}{9} WL^2$

WHEN TWO WAY REINFORCEMENT IS USED THE BENDING MOMENT "M" MAY BE CONSIDERED EQUAL TO $\frac{1}{11} WL^2$ IN EACH DIRECTION

NOTE - SLABS OF THIS TYPE ARE NOT CONSIDERED CONTINUOUS WHEN THERE ARE LESS THAN 3 SPANS.

SECTION THRO CONTINUOUS SLAB - ONE WAY REINFORCEMENT·

WHEN M - BENDING MOMENT IN FOOT POUNDS
W - LIVE + DEAD LOAD PER SQUARE FOOT
L = SPAN IN FEET

THEN $M = \frac{1}{10} WL^2$

WHEN TWO WAY REINFORCEMENT IS USED - THE BENDING MOMENT "M" MAY BE CONSIDERED EQUAL TO $\frac{1}{12} WL^2$ IN EACH DIRECTION·

Bending Moment in Slabs for Various Loads and Spans.

For slabs of various spans under total uniform live and dead loads per square foot, ranging from five-foot to twenty-four-foot spans, and from 75 pounds to 1000 pounds load per square foot, the bending moment in foot pounds is given in tables on pages 23, 24 and 25. These tables are used in connection with the tables given on pages 31 to 42.

Example: What is the bending moment in foot pounds for a simple span of 12 feet of the one-way type of reinforcement under a load of 250 pounds per square foot? Answer, 4500 foot pounds.

Example: If the span is simple, uniformly loaded, of the two-way type of reinforcement, the panel being square, what bending moment, in each direction, will be attained for a panel 14'x14', under a total load of 500 pounds per square foot (see page 20 and page 14)?
Answer: 0.5x0.8x500-200 pounds per square foot, the amount to be used in the table. The bending moment would be 4900 foot pounds per foot of width in each direction in the slab.

The bending moment in slabs of the continuous one-way type of reinforcement, and of the continuous two-way type of reinforcement may be found in the same way by reducing the total according to the coefficients called for upon page 20.

Bending Moments in Slabs Per Foot of Width.

BENDING MOMENT IN FOOT POUNDS IN SLABS FOR VARIOUS SPANS & LOADS PER SQ.FT

$M = \frac{1}{8} WL^2$	LOAD PER SQUARE FOOT LIVE + DEAD					
SPAN OF SLAB IN FEET	75#	100#	125#	150#	175#	200#
5'	235	310	390	470	550	625
6'	340	450	560	675	785	900
7'	460	615	770	920	1075	1130
8'	600	800	1000	1200	1400	1600
9'	760	1010	1260	1520	1770	2020
10'	940	1250	1565	1875	2190	2500
11'	1130	1510	1880	2260	2640	3000
12'	1350	1800	2250	2700	3150	3600
13'	1600	2100	2650	3150	3700	4250
14'	1850	2450	3100	3650	4300	4900
15'	2100	2800	3500	4200	4900	5600
16'	2400	3200	4100	4800	5600	6400
17'	2700	3600	4500	5400	6300	7200
18'	3100	4100	5100	6100	7100	8100
19'	3400	4500	5600	6800	7900	9000
20'	3750	5000	6250	7500	8750	10000
21'	4100	5500	6900	8300	9600	11000
22'	4500	6000	7600	9000	10500	12000
23'	5000	6600	8300	10000	11600	13200
24'	5400	7200	9000	10800	12500	14300

Bending Moments in Slabs Per Foot of Width.

BENDING MOMENT IN FOOT POUNDS IN SLABS FOR VARIOUS SPANS & LOADS PER SQ. FT.

$M=\frac{1}{8}WL^2$ ·LOAD PER SQUARE FOOT·
·LIVE + DEAD·

SPAN OF SLAB IN FEET	250#	300#	350#	400#	450#	500#
5'	780	940	1100	1250	1400	1560
6'	1150	1350	1650	1800	2050	2250
7'	1550	1850	2150	2450	2750	3050
8'	2000	2400	2800	3200	3600	4000
9'	2550	3000	3550	4050	4600	5100
10'	3150	3750	4400	5000	5650	6250
11'	3800	4550	5300	6100	6800	7600
12'	4500	5400	6300	7200	8100	9000
13'	5300	6400	7400	8500	9500	10600
14'	6100	7400	8600	9800	11100	12300
15'	7100	8500	9900	11300	12700	14100
16'	8000	9600	11200	12800	14400	16000
17'	9000	10800	12700	14500	16300	18000
18'	10100	12200	14200	16200	18200	20300
19'	11300	13600	15800	18000	20400	22600
20'	12500	15000	17500	20000	22500	25000
21'	13800	16500	19300	22000	24700	27500
22'	15200	18200	21200	24200	27300	30200
23'	16500	19800	23200	26500	29700	33000
24'	18000	21600	25200	28800	32400	36000

Bending Moments in Slabs Per Foot of Width.

BENDING MOMENT IN FOOT POUNDS IN SLABS FOR VARIOUS SPANS & LOADS PER SQ. FT

$M = \frac{1}{8}wL^2$		LOAD PER SQUARE FOOT LIVE + DEAD					
		550#	600#	700#	800#	900#	1000#
SPAN OF SLAB IN INCHES	5'	1720	1875	2200	2500	2820	3125
	6'	2500	2700	3150	3600	4050	4500
	7'	3400	3700	4300	4900	5500	6150
	8'	4400	4800	5600	6400	7200	8000
	9'	5370	6100	7100	8100	9100	10100
	10'	6870	7500	8750	10000	11250	12500
	11'	8300	9100	10600	12100	13600	15100
	12'	9900	10800	12600	14400	16200	18000
	13'	11600	12700	14800	16900	19000	21100
	14'	13500	14700	17200	19600	22000	24500
	15'	15500	17000	19600	22500	25400	28100

Properties of Slabs.

On page 6, the method of calculation of a reinforced concrete beam having a depth of one inch from the extreme compression fibre to the center or tension, is explained. The table shown on page 28 indicates the properties of slabs, based upon the principles developed in the discussion of the slab one inch in depth.

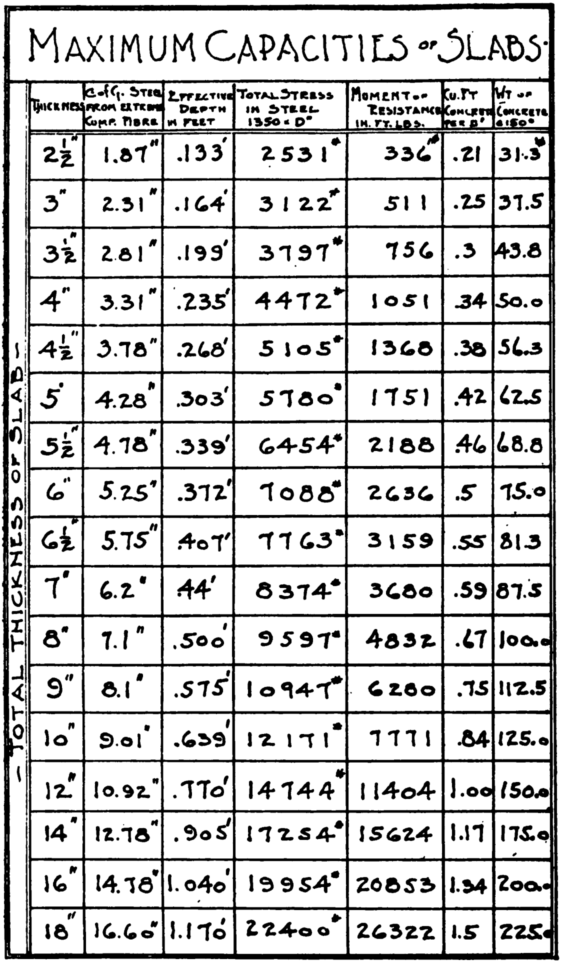
In the first column the different thicknesses of the slabs from 2½" to 18" are given. This "thickness of the slab" means the entire slab, including the concrete on the under side of the rod. The second column gives what has been previously explained as the depth of the slab in inches, meaning the distance from the center of tension to the extreme fibre in compression. This depth is arrived at by the use of one-half inch of concrete, outside of the metal, and by the assumption of the size of rods which would probably be used in the slab under consideration. In the third column is given the effective depth in feet, which is equal to 0.85 of the depth, as previously explained. The fourth column indicates the tension which would be required in the slab, in the form of steel, if the slab were stressed in bending, so as to develop its full capacity, at an extreme fibre strain of 500 pounds to the square inch. The fifth column gives the moment of resistance in foot pounds, for the various slabs. This moment of resistance is a maximum capacity of the slab, and will not be increased by an additional amount of steel over that called for in column Four. Column Six indicates the cubic feet of concrete per spuare foot of slab, and is to be used in estimating purposes. Column Seven indicates the weight of the concrete calculated at 150 pounds to the cubic foot. This is used in connection with the calculation of the dead load.

This table is useful in determining the thickness of the slab and the tension required, after having calculated the bending moment in foot pounds.

Example: If a slab has such a span and load as to develop a bending moment of 2600 foot pounds per foot of width, what slab will be required to furnish the proper moment of resistance?

Answer: A slab six inches thick will provide a moment of resistance of 2636 foot pounds per foot of width, and the tension required in the steel will be 7088 pounds; the weight of the slab will be 75 pounds per square foot, and it will contain 0.5 of a cubic foot of concrete.

Properties of Slabs.



MAXIMUM CAPACITIES OF SLABS.

TOTAL THICKNESS OF SLAB

THICKNESS	C. of G. STEEL FROM EXTREME COMP. FIBRE	EFFECTIVE DEPTH IN FEET	TOTAL STRESS IN STEEL 1350 × D″	MOMENT OF RESISTANCE IN. FT. LBS.	CU. FT CONCRETE PER □′	WT OF CONCRETE @150#
2½″	1.87″	.133′	2531#	336#	.21	31.3#
3″	2.31″	.164′	3122#	511	.25	37.5
3½″	2.81″	.199′	3797#	756	.3	43.8
4″	3.31″	.235′	4472#	1051	.34	50.0
4½″	3.78″	.268′	5105#	1368	.38	56.3
5″	4.28″	.303′	5780#	1751	.42	62.5
5½″	4.78″	.339′	6454#	2188	.46	68.8
6″	5.25″	.372′	7088#	2636	.5	75.0
6½″	5.75″	.407′	7763#	3159	.55	81.3
7″	6.2″	.44′	8374#	3680	.59	87.5
8″	7.1″	.500′	9597#	4832	.67	100.0
9″	8.1″	.575′	10947#	6280	.75	112.5
10″	9.01″	.639′	12171#	7771	.84	125.0
12″	10.92″	.770′	14744#	11404	1.00	150.0
14″	12.78″	.905′	17254#	15624	1.17	175.0
16″	14.78″	1.040′	19954#	20853	1.34	200.0
18″	16.60″	1.170′	22400#	26322	1.5	225.0

Moment of Resistance of Slabs.

The tables from page 31 to page 42 give the moment of resistance in the various thicknesses of slab, ranging from 2½″ to 12″ total thickness, this thickness including the concrete on the under side of the rods. These tables are to be used in connection with the tables of bending moment in foot pounds given on pages 23 to 25.

From the theory of the concrete beam given on page 6 it will be seen that the safe capacity of any thickness of slab, is reached when the concrete has been strained to 500 pounds per square inch in the extreme fibre, and that a greater amount of steel placed in the slab than is required to produce this compression is wasted. In these tables the top figure in any column, indicates the maximum moment of resistance in foot pounds, which the slab is capable of resisting, and rods spaced closer together than the corresponding distance shown will be of no advantage.

Example: What thickness of slab and what sizes and spacing of bars will give a resistance of 4,900 foot pounds per foot of width? Answer: An eight-inch slab with ⅝″ rods 6″ on centers, or a 9″ slab with ¾″ rods 10″ on centers, or a 10″ slab with ⅞″ rods 13″ on centers.

It is obvious that the first one is most economical, as the maximum amount of strength is being obtained from a minimum quantity of concrete. For the sake of economy, however, it would be well to use ¾″ rods spaced such a distance on centers as to give the same tension as the ⅝″ rods 6″ on centers. This may be obtained by referring to table on page 60. The advantage gained is that the price of ¾″ rods is slightly less than that of ⅝″, and that less pieces need be handled, thus reducing the cost of labor. Rods may be spaced within a slab with safety up to a distance on centers equal to double the thickness of the slab.

Where the surface of the slab is finished for a wearing surface, it may be considered as a part of the total thickness of the slab, provided it is placed at the same time as the body so that it is thoroughly bonded together; but if this wearing surface is placed at a later date, it should in no case be considered as giving any strength to the slab.

Two and One-half Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE.

IN FOOT POUNDS OF A SLAB 2½" THICK.
WITH VARIOUS SIZE AND SPACING OF RODS.

		DIAMETER OF ROD.			
		1/4"	5/16"	3/8"	
	EFFECTIVE DEPTH	.133'	.130		
SPACING OF RODS UNIT STRESS 16000#	3½"	336			
	4"	313			
	4½"	278			
	5"	250			
	5½"	227			
	6"	210	319		
	6½"	192	294		
	7"		273		
	7½"		255		

Three Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 3" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

		DIAMETER OF ROD			
		$\frac{1}{4}$"	$\frac{5}{16}$"	$\frac{3}{8}$"	
	EFFECTIVE DEPTH	.168	.166	.163	
SPACING OF RODS UNIT STRESS 16000#	4"	396			
	4$\frac{1}{2}$"	351			
	5"	316	488		
	5$\frac{1}{2}$"	287	444		
	6"	263	407		
	6$\frac{1}{2}$"	243	375	511	
	7"	226	348	493	
	7$\frac{1}{2}$"	211	325	460	
	8"	198	305	431	

Three and One-half Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE
IN FOOT POUNDS OF A SLAB 3½" THICK
WITH VARIOUS SIZE & SPACING OF RODS

SPACING OF RODS UNIT STRESS 16000#□"		DIAMETER OF ROD			
		1/4"	5/16"	3/8"	7/16"
	EFFECTIVE DEPTH	.204	.201	.199	.197
	4"	481	740		
	4½"	427	657		
	5"	385	591		
	5½"	350	537	756	
	6"	320	493	703	
	6½"		455	649	
	7"		422	602	
	7½"		394	562	757
	8"		370	527	710

Three Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 3" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

		DIAMETER OF ROD			
		$\frac{1}{4}$"	$\frac{5}{16}$"	$\frac{3}{8}$"	
	EFFECTIVE DEPTH	.168	.166	.163	
SPACING OF RODS UNIT STRESS 16000#	4"	396			
	4½"	351			
	5"	316	488		
	5½"	287	444		
	6"	263	407		
	6½"	243	375	511	
	7"	226	348	493	
	7½"	211	325	460	
	8"	198	305	431	

Three and One-half Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 3½" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS UNIT STRESS 16000#□	DIAMETER OF ROD			
	¼"	5/16"	⅜"	7/16"
EFFECTIVE DEPTH	.204	.201	.199	.197
4"	481	740		
4½"	427	657		
5"	385	591		
5½"	350	537	756	
6"	320	493	703	
6½"		455	649	
7"		422	602	
7½"		394	562	757
8"		370	527	710

Four-Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 4" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS UNIT STRESS 16000#	DIAMETER OF ROD			
	$\frac{1}{4}$"	$\frac{5}{16}$"	$\frac{3}{8}$"	$\frac{7}{16}$"
EFFECTIVE DEPTH	.239'	.236'	.234	.232'
4"	563	868		
4½"	500	772	1051	
5"	450	695	993	
5½"	409	631	901	
6"	375	579	827	
6½"		534	763	1030
7"		492	708	956
7½"		463	661	892
8"		434	620	836

Four and One half Inch Slabs One Foot Wide

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 4½" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

·SPACING OF RODS· UNIT STRESS 16000# □"	·DIAMETER OF RODS·			
	5/16"	3/8"	7/16"	1/2"
EFFECTIVE DEPTH	.27'	.27'	.26'	.26'
4"	997	1370		
4½"	887	1267		
5"	798	1140		
5½"	725	1036	1370	
6"	665	950	1284	
6½"	613	877	1185	
7"	570	814	1101	
7½"	532	760	1027	1310
8"	499	713	963	1248

Five Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE.

IN FOOT POUNDS FOR A SLAB 5" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS. UNIT STRESS 16000#	DIAMETER OF RODS.				
		3/8"	7/16"	1/2"	5/8"
	EFFECTIVE DEPTH	.3'	.3'	.3'	.3'
	5"	1271	1751		
	5½"	1170	1583		
	6"	1074	1453		
	6½"	991	1340	1739	
	7"	920	1245	1615	
	7½"	859	1161	1507	
	8"	800	1080	1413	
	9"	706	961	1256	
	10"	636	865	1130	1767

Six Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS FOR A SLAB 6" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

	DIAMETER OF RODS.				
		7/16"	1/2"	5/8"	3/4"
	EFFECTIVE DEPTH	.37'	.37'	.36'	.36'
SPACING OF RODS. UNIT STRESS 16000 #□"	5"	2158	2636		
	6"	1800	2331		
	7"	1542	1996		
	8"	1349	1747	2636	
	9"	1200	1553	2356	
	10"	1079	1398	2120	
	11"	979	1269	1925	
	12"	900	1165	1767	2544
	14"	771	998	1514	2180

Seven Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE
IN FOOT POUNDS FOR A SLAB 7" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS UNIT STRESS 16000#	DIAMETER OF RODS			
	1/2"	5/8"	3/4"	7/8"
EFFECTIVE DEPTH	.44'	.44'	.42'	.42'
6"	2764			
7"	2368	3623		
8"	2073	3239		
9"	1842	2880		
10"	1658	2591	3562	
11"		2354	3239	
12"		2160	2969	
14"		1851	2545	3463
16"			2226	3030

Eight Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE
IN FOOT POUNDS FOR A SLAB 8" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS: UNIT STRESS 16000#	DIAMETER OF RODS			
	1/2"	5/8"	3/4"	7/8"
EFFECTIVE DEPTH	.5'	.5'	.49'	.49'
6"	3141	4909		
7"	2692	4208		
8"		3681		
9"		3272	4653	
10"		2945	4188	
11"		2677	3807	
12"		2454	3489	4714
14"			2991	4040
16"				3535

Nine Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS FOR A SLAB 9" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

		DIAMETER OF RODS			
		5/8"	3/4"	7/8"	1"
	EFFECTIVE DEPTH	.58'	.58'	.58'	.56'
·SPACING OF RODS· UNIT STRESS 16000#	6"	5694			
	7"	4881			
	8"	4271	6150		
	9"	3796	5466		
	10"	3416	4920	6465	
	11"	3106	4473	5877	
	12"		4100	5397	
	14"		3514	4618	6030
	16"			4040	5277

Ten Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 10" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS. UNIT STRESS 16000#□"	DIAMETER OF RODS			
	$\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{7}{8}$"	1"
EFFECTIVE DEPTH	.63'	.63'	.6'	.6'
6"	6185			
7"	5300	7633		
8"	4638	6678		
9"	4128	5936	7696	
10"	3710	5342	6927	
11"		4854	6292	
12"		4453	5772	7540
14"			4947	6461
16"			4329	5655

Twelve Inch Slabs One Foot Wide.

MOMENT OF RESISTANCE

IN FOOT POUNDS OF A SLAB 12" THICK
WITH VARIOUS SIZE AND SPACING OF RODS

SPACING OF RODS UNIT STRESS 16000#□"	DIAMETER OF RODS-			
	$\frac{5}{8}$"	$\frac{3}{4}$"	$\frac{7}{8}$"	1"
EFFECTIVE DEPTH.	.80'	.80'	.78'	.78'
6"	7854	11310		
7"	6730	9693		
8"	5890	8481	11256	
9"		7540	10005	
10"		6786	9005	11762
11"		6164	8186	10692
12"		5655	7504	9801
14"			6432	8400
16"				7351

Capacities of Slabs.

The tables given upon pages 44 and 45 are calculated for simple one-way spans where the bending moment is equal to $\frac{1}{8}W\ L^2$, W being the total dead and live load per square foot. In the table this total load per square foot is put at the top, while the span of the slab is given at the left side. In the body of the table is given the thickness of the slab in inches and the total tension required therein, in pounds per foot of width, to give the slab the proper strength to resist the load on the span given.

Example: For a simple one-way reinforcement of the type shown upon page 16 and having a span of 12 feet, what thickness of slab will be required and what tension will be necessary per foot of width to carry a total dead and live load of 175 pounds per square foot? Answer: The total thickness of the slab is 6.50 inches and the tension required 7,800 pounds per foot of width.

Example: In a square panel 14′ x 14′ of the simple two-way type of reinforcement, what thickness of slab and what tension per foot of width in each direction will be required to carry a total live and dead load of 500 pounds per square foot? (See page 14 and page 20.) Answer: 0.5 x 0.8 x 500 -200 pounds per square foot. The thickness of the slab from the table will be 7.98 inches, or practically 8 inches, and the tension in each direction per foot of width will be 9,750 pounds.

In case the panel is oblong, the coefficients given on page 14 are to be used in determining the amount of load which goes in each direction, instead of considering that one-half of it goes each way as above.

Capacities of Slabs.

	·LOAD PER SQUARE FOOT· LIVE + DEAD·					
SPAN	75#	100#	125#	150#	175#	200#
5'	2.25" 2130#	2.49" 2430#	2.70" 2750#	2.90" 3000#	3.09" 3250#	3.25" 3500#
6'	2 58" 2550	2.85" 2930	3.11" 3280	3.34" 3600	3.56" 3900	3.75" 4110
7'	2 89" 2960	3.23" 3420	3.54" 3860	3.79" 4200	4.04" 4520	4.27" 4850
8'	3.19" 3400	3.59" 3900	3.94" 4400	4.24" 4800	4.52" 5200	4.82" 5550
9'	3.50" 3800	3.93" 4400	4.37" 4925	4.72" 5400	5.02" 5800	5.32" 6200
10'	3.84" 4250	4.32" 4900	4.77" 5450	5.15" 6000	5.52" 6500	5.85" 6900
11'	4.17" 4700	4.72" 5400	5.17" 6000	5.62" 6600	6.00" 7100	6.35" 7600
12'	4.47" 5100	5.07" 5900	5.57" 6550	6.05" 7200	6.50" 7800	6.85" 8250
13'	482" 5550	5.42" 6400	6.00" 7100	6.50" 7800	6.98" 8400	7.48" 9050
14'	5.12" 6000	5.8" 6800	6.65" 7700	6 98" 8400	7 48" 9050	7.98" 9750
15'	5.42" 6400	6.15" 7300	6 83" 8200	7.43" 9000	7.98" 9750	8.46" 10300
16'	5.75" 6800	6.55" 7850	7.33" 8800	7.88" 9600	8.46" 10300	9.00" 11100
17'	6.05" 7200	6 85" 8400	7.68" 9400	8.31" 10100	8.91" 11000	9.51" 11800
18'	6.45" 7800	7.33" 8800	8.11" 9850	8.81" 10800	9.41" 11600	10.00" 12500
19'	6.78" 8100	7.68" 9400	8.46" 10300	9.31" 11500	9.95" 12500	10.55" 13100
20'	7.08" 8550	8.06" 9850	8.91" 11000	9.75" 12000	10.45" 13000	11.10" 13900
21'	7.33" 8800	8.41" 10200	9.31" 11500	10.15" 12500	10.85" 13500	11.55" 14500
22'	7.68" 9400	8.81" 10800	9.75" 12000	10.55" 13100	11.37" 14100	12.00" 15100
23'	8.00" 9850	9.11" 11200	10.15" 12500	11.10" 13900	11.97" 15100	12 67" 16000
24'	8 31" 10100	9.51" 11800	10.55" 13100	11.50" 14400	12.27" 15400	13.00" 16500

Capacities of Slabs.

LOAD PER SQUARE FOOT
·LIVE + DEAD·

SPAN	250#	300#	350#	400#	450#	500#
5'	3.55" 3850#	3.84" 4250#	4.09" 4600#	4.29" 4860#	4.56" 5200#	4.76" 5500#
6'	4.17" 4700	4.47" 5100	4.87" 5600	5.07" 5900	5.37" 6300	5.57" 6600
7'	4.72" 5400	5.12" 6000	5.42" 6400	5.77" 6850	6.11" 7200	6.40" 7650
8'	5.28" 6200	5.70" 6800	6.15" 7300	6.55" 7800	6.87" 8300	7.28" 8800
9'	5.90" 7000	6.36" 7800	6.85" 8250	7.28" 8800	7.71" 9350	8.00" 9800
10'	650" 7800	7.03" 8500	7.58" 9200	8.00" 9850	8.50" 10400	8.88" 11100
11'	7.05" 8550	7.71" 9300	8.26" 10100	8.81" 10800	9.24" 11500	9.71" 12000
12'	7.68" 9400	8.31" 10100	8.91" 11000	9.51" 11750	10.05" 12500	10.58" 13100
13'	8.26" 10100	9.01" 11000	9.61" 12000	10.25" 12600	10.85" 13500	11.40" 14500
14'	8.81" 10800	9.61" 12000	10.35" 13000	10.90" 13700	11.65" 14600	12.20" 15300
15'	9.41" 11600	10.25" 12600	11.05" 13800	11.75" 14700	12.43" 15600	13.08" 16500
16'	10.00" 12400	10.90" 13550	11.68" 14550	12.48" 15700	13.20" 16600	13.88" 17500
17'	10.55" 13000	11.45" 14450	12.48" 15750	13.20" 16600	13.94" 17500	14.64" 18500
18'	11.15" 14000	12.18" 15250	13.08" 16500	13.94" 17500	14.74" 18550	
19'	11.75" 14600	12.88" 16200	13.79" 17400	14.64" 18500		
20'	12.28" 15300	13.44" 17000	14.54" 18300			
21'	12.87" 16200	14.14" 18000	15.14" 19250			
22'	13.48" 17000	14.74" 18600				
23'	14.14" 18000	15.34" 19500				
24'	14.64" 18500	16.10" 20500				

Properties of Wire

The properties of wire given upon page 48 are according to the Trenton wire guage. Only such sizes of wire are given as may be found useful in reinforcing of concrete. Sizes smaller than No. 12 will never be used, and sizes larger than No. 3 will probably be replaced by steel rods given in another table.

Area of Wire Per Foot of Width.

The table on page 49 gives the area of wire, in square inches per foot of width, in slabs, for the various gauges from No. 1 to No. 12, and spacing from 1″ to 12″. This is based upon the sizes of wire given in the table on page 48, and is according to the Trenton wire gauge.

Example: If a form of wire mesh is to be used as reinforcement requiring a total area of 0.12 of a square inch of metal per foot of width, what sizes and spacing of wire should be used?

Answer: No 9 wire spaced 1½″ on centers, or No. 8 wire spaced 2″ on centers, or No. 3 wire spaced 4½″ on centers, etc.

Tension in Wire per Foot of Width

Wire is manufactured with a very high carbon, and some manufacturers recommend a safe capacity on wire, of 40,000 pounds or 50,000 pounds per square inch, the wire which they supply testing up to 100,000 pounds elastic limit, or even higher. We do not consider this good practice, and in fact would not advise the use of any tension higher than 28,000 pounds per square inch.

The table on page 50 gives the total tension produced in wire, for Trenton wire guages, from No. 1 to No. 12, and spacing from 1″ to 6″ where the fibre strain is 16,000 pounds, 20,000 pounds, 24,000 pounds and 28,000 pounds per square inch.

In case it should be found necessary to use tension values of 32,000 pounds, 40,000 pounds or 48,000 pounds, they can be arrived at by doubling the quantities given in the table.

Example: Where a metal fabric having No. 7 wire spaced 3″ on centers is imbedded in a slab, what tension value is given to the slab per foot of width, when the allowable working load is 24,000 pounds per square inch of metal? Answer: 2,300 pounds per foot of width.

Properties of Wire—Trenton Wire Guage.

SIZE AND WEIGHT OF IRON AND STEEL WIRE

WIRE GUAGE No.	DIAMETER IN DECIMALS OF AN INCH	AREA OF SECTION IN SQ. IN.	WEIGHT OF 1 FOOT IN POUNDS	FEET TO THE POUND
1	.285	.06379	.2153	4.645
2	.265	.05515	·1861	5.374
3	.245	.04714	.1591	6.286
4	.225	.03976	·1342	7.454
5	.205	.03301	.1114	8.976
6	.190	.02835	.09566	10.453
7	.175	.02405	.08115	12.322
8	.160	.02011	.06786	14.736
9	.145	.01651	.05571	17.950
10	.130	.01327	.04477	22.333
11	.1175	.01084	.03658	27.340
12	.105	.00866	.02922	34.219

Area of Wire.

TOTAL AREA OF WIRE IN SQUARE INCHES PER FOOT WIDTH

		GUAGE AND DIAMETER IN INCHES											
	GUAGE	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
	DIA.	.285	.265	.245	.225	.205	.190"	.175"	.160"	.145"	.130"	.1175"	.105"
SPACING OF WIRE IN INCHES	1"	.764	.660	.564	.476	.396	.340	.284	.240	.196	.160	.128	.104
	1½"	.510	.440	.375	.310	.264	.222	.192	.160	.128	.104	.087	.065
	2"	.382	.330	.282	.238	.198	.170	.144	.120	.098	.080	.064	.052
	2½"	.310	.265	.225	.185	.158	.134	.115	.096	.077	.062	.052	.038
	3"	.254	.220	.188	.158	.133	.114	.096	.080	.066	.052	.044	.034
	3½"	.220	.190	.161	.134	.113	.096	.082	.069	.055	.045	.037	.028
	4"	.191	.165	.141	.119	.099	.085	.072	.060	.049	.040	.032	.026
	4½"	.171	.147	.125	.105	.088	.075	.064	.053	.043	.035	.029	.021
	5"	.155	.132	.112	.094	.079	.067	.058	.048	.038	.031	.026	.020
	5½"	.140	.120	.103	.085	.072	.061	.052	.044	.035	.028	.024	.017
	6	.127	.110	.094	.079	.066	.057	.048	.040	.033	.026	.022	.017
	6½"	.118	.102	.087	.072	.061	.052	.044	.037	.030	.024	.020	.015
	7"	.110	.094	.081	.067	.057	.048	.041	.034	.027	.022	.019	.013
	8"	.095	.082	.070	.059	.049	.042	.036	.030	.024	.020	.016	.013
	9"	.085	.073	.063	.052	.044	.037	.032	.026	.021	.017	.014	.011
	12"	.064	.055	.047	.039	.033	.028	.024	.020	.016	.013	.011	.008

Tension in Wire.

·TENSION PER FOOT OF WIDTH·

TENSION @ 16000, 20000, 24000 28000

·SPACING OF WIRE IN INCHES·	FIBRE STRAIN PER SQ. IN	WIRE GUAGE & DIAMETER IN INCHES					
		•1	•2	•3	•4	•5	•6
		0.285"	0.265"	0.245"	0.225"	0.205"	0.190"
1"	16000	12200	10600	9000	8400	6350	5450
	20000	15200	13200	11300	10500	7900	6800
	24000	18300	15800	13500	12600	9500	8200
	28000	21300	18500	15800	14700	11100	9500
1½"	16000	8150	7050	6000	4950	4400	3550
	20000	10200	8800	7500	6200	5300	4450
	24000	12200	10550	9000	7450	6300	5300
	28000	14200	12300	10500	8700	7400	6200
2"	16000	6100	5250	4500	3800	3150	2700
	20000	7600	6600	5600	4750	3900	3400
	24000	9200	7900	6700	5700	4750	4100
	28000	10700	9200	7900	6700	5500	4750
2½"	16000	4900	4250	3600	2950	2500	2100
	20000	6200	5300	4500	3700	3300	2650
	24000	7400	6400	5400	4450	3800	3200
	28000	8700	7400	6300	5150	4400	3750
3"	16000	4050	3500	3000	2700	2150	1800
	20000	5050	4400	3750	3350	2650	2250
	24000	6100	5300	4500	4000	3200	2750
	28000	7100	6200	5250	4700	3750	3200
3½"	16000	3500	3050	2550	2150	1800	1500
	20000	4400	3800	3200	2650	2250	1900
	24000	5250	4550	3850	3100	2600	2300
	28000	6100	5300	4500	3750	3150	2700
4"	16000	3050	2600	2250	1900	1550	1350
	20000	3800	3300	2800	2350	1950	1700
	24000	4600	3950	3400	2850	2350	2050
	28000	5300	4600	3950	3300	2750	2350
4½"	16000	2700	2350	2000	1650	1400	1200
	20000	3400	2900	2500	2100	1750	1500
	24000	4100	3500	3000	2500	2100	1800
	28000	4750	4100	3500	2900	2450	2100
5"	16000	2450	2100	1750	1500	1250	1050
	20000	3100	2650	2200	1850	1550	1350
	24000	3700	3150	2650	2250	1900	1600
	28000	4300	3700	3100	2600	2200	1850
5½"	16000	2250	1900	1650	1350	1150	950
	20000	2800	2400	2050	1700	1450	1200
	24000	3350	2850	2450	2000	1700	1450
	28000	3900	3350	2850	2350	2000	1700
6"	16000	2000	1750	1500	1250	1050	900
	20000	2500	2200	1850	1550	1300	1100
	24000	3000	2650	2250	1900	1550	1350
	28000	3500	3050	2600	2200	1800	1600

Tension in Wire.

TENSION PER FOOT OF WIDTH

TENSION @ 16000 LBS, 20000 LBS, 24000 LBS, 28000 LBS

SPACING OF WIRE IN INCHES	FIBRE STRAIN PER SQ.IN.	WIRE GUAGE & DIAMETER IN INCHES					
		#7	#8	#9	#10	#11	#12
		0.175"	0.160"	0.145"	0.130"	0.1175"	0.105
1"	16000	4550	3850	3100	2550	2050	1650
	20000	5650	4800	3900	3200	2550	2050
	24000	6800	5750	4700	3800	3050	2500
	28000	7900	6700	5500	4450	3550	2900
1½"	16000	3100	2550	2050	1650	1400	1050
	20000	3850	3200	2550	2050	1750	1300
	24000	4600	3800	3050	2500	2100	1550
	28000	5400	4500	3550	2900	2450	1800
2"	16000	2300	1900	1550	1250	1000	820
	20000	2850	2400	1950	1600	1250	1000
	24000	3450	2850	2350	1900	1500	1200
	28000	4000	3350	2750	2250	1750	1400
2½"	16000	1850	1550	1200	1000	850	600
	20000	2300	1900	1550	1200	1050	750
	24000	2750	2300	1850	1450	1250	900
	28000	3200	2700	2150	1700	1450	1050
3"	16000	1500	1250	1050	800	700	550
	20000	1900	1600	1300	1000	850	650
	24000	2300	1900	1550	1250	1050	800
	28000	2650	2250	1850	1450	1200	950
3½"	16000	1300	1100	850	700	600	450
	20000	1650	1350	1100	900	750	550
	24000	1950	1650	1300	1050	900	650
	28000	2300	1900	1550	1250	1050	750
4"	16000	1150	960	780	640	510	410
	20000	1440	1200	980	800	640	520
	24000	1720	1440	1170	960	760	620
	28000	2010	1670	1370	1120	890	720
4½"	16000	1020	850	690	560		
	20000	1280	1060	860	700		
	24000	1530	1260	1030	840		
	28000	1780	1470	1200	980		
5"	16000	930	770	610			
	20000	1160	960	760			
	24000	1400	1150	910			
	28000	1600	1340	1060			
5½"	16000	830	700				
	20000	1040	880				
	24000	1250	1060				
	28000	1450	1220				
6"	16000	770					
	20000	960					
	24000	1150					
	28000	1340					

Properties of Round Rods.

Round rods here illustrated are such rods as it is assumed will be commonly used in the reinforcing of concrete. 1-16″ sizes above ¾″ are omitted for the reason that it is not advisable to use them on account of running into such a variety of sizes. The designer can almost invariably adjust the design so as to use the sizes of rods here given, and a little study in this direction will be well repaid in the added convenience in securing the material.

Area of Rods Per Foot of Width.

The table on page 58 gives the area of rods in square inches per foot of width, in slabs, for the various diameters, from ¼″ to 1″ and spacing from 3″ to 16″.

Example: What size of rods and spacing will give an area of 0.74 of a square inch of metal per foot of width? Answer: ½″ rods 3″ on centers, or 9-16″ rods 4″ on centers, or 11-16″ rods 6″ on centers, or ¾″ rods 7″ on centers. The last is the most economical to use because the ¾″ size comes under the base price for steel, and rods of a small size will cost an extra amount. The spacing of 7″ is not too wide, for it is less than double the thickness of a 10″ slab, and it will be seen by reference to page 28 that no slab less than 10″ will require, when fully loaded a tension equal to 12100 pounds, which is the strength of ¾″ rods 7″ on centers. At a fibre strain of 16,000 pounds per square inch a 10″ slab is the thickness which must necessarily be used. If so large an area as 0.74 of an inch of metal is taken per foot of width, it would be more economical to use a still larger size bar, spacing wider apart in order to economize in the handling. 1″ rods 12″ on centers would be the size and spacing recommended.

Tension in Rods Per Foot of Width.

Round rods of a high carbon for use as reinforcement may be had at a slight advance in cost over plain open-hearth or Bessemer steel. The steel rods should never be stressed at more than one-half the elastic limit of the steel, and in no case beyond 24,000 pounds per square inch. Ordinary Bessemer or open-hearth steel as found on the market should be figured at a safe fibre strain of 16,000 pounds per square inch.

The tables on pages 59 and 60 give the tension in steel rods for the various sizes from ¼″ to 1″, with spacing from 3″ to 8″, and for fibre strains of 16,000 pounds, 20,000 pounds and 24,000 pounds per square inch.

Example: If ¾″ bars are placed 8″ on centers, what tension is developed at a fibre strain of 16,000 pounds per square inch. Answer: 10600 pounds.

These tables are conveniently used in connection with the tables given upon pages 44 and 45, where the thickness of the concrete slab is given together with the required number of pounds tension to be supplied in the steel.

Weight of Rods Per Square Foot.

When steel rods are placed within slabs, it is convenient for estimating purposes to reduce the weight of the steel to a square foot basis in order to take off the quantities conveniently. The table on page 61 gives the weights of rods for various sizes, and spaces center to center, where the rods are laid in one direction only. In case the reinforcement is of the two-way type, and same reinforcemtnt in each direction, the weights given in the tables should be doubled. In order to make an estimate accurate, the extra length of rods required on each span should be added to the weights given in the table by means of a percentage. Continuous reinforcement usually requires about 25% additional weight per square foot in order to make up for the extra length of the rod which laps over into the adjoining panel.

Example: Where ¾″ rods are used for continuous construction spaced 12″ on centers, the reinforcement being of the two-way type, how much will the rods weigh per square foot of slab?

Answer: $1.502\times 2+25\%=3.755$ pounds per square foot.

Properties of Round Rods.

·ROUND RODS·

DIAMETER OF ○ ROD	WEIGHT OF ROUND ROD ONE FOOT LONG	AREA OF ROUND ROD IN SQUARE INCHES	TENSILE STRENGTH @ 16000° PER SQUARE INCH
1/4"	.167*	.0491	785
5/16"	.261*	.0767	1227
3/8"	.375	.1104	1766
7/16"	.511	.1503	2405
1/2"	.667	.1963	3141
9/16"	.845	.2485	3976
5/8"	1.043	.3068	4909
11/16"	1.262	.3712	5939
3/4"	1.502	.4418	7069
7/8"	2.044	.6013	9621
1"	2.670	.7854	12566
1 1/8"	3.379	.9940	15904
1 1/4"	4.173	1.2272	19635
1 3/8"	5.049	1.4849	23758
1 1/2"	6.008	1.7671	28274
1 5/8"	7.051	2.0739	33182

Properties of Round Rods.

·ROUND RODS·

Diameter of ○ Rod	Weight of Round Rod One Foot Long	Area of Round Rod in Square Inches	Tensile Strength @ 16000# per Square Inch.
1¾"	8.178#	2.4053	38485
1⅞"	9.388	2.7612	44179
2"	10.680	3.1416	50265
2⅛"	12.060	3.5466	
2¼"	13.520	3.9761	
2⅜"	15.070	4.4301	
2½"	16.690	4.9087	
2⅝"	18.400	5.4119	
2¾"	20.200	5.9396	
2⅞"	22 070	6.4918	
3"	24.030	7.0686	
3⅛"	26.080	7.6699	
3¼"	28.200	8.2958	
3½"	32.710	9.6211	
3¾"	37.560	11.0450	
4"	42.730	12.5660	

Area of Rods.

AREA OF STEEL IN SQUARE INCHES.
PER FOOT WIDTH FOR RODS AND SPACING GIVEN.

	ROD DIAMETER										
SPACING OF RODS IN INCHES.	1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	7/8"	1"
3"	.196	.307	.441	.601	.785	.994	1.227	1.485	1.767	2.405	3.141
3½"	.168	.263	.378	.515	.673	.852	1.052	1.272	1.514	2.061	2.692
4"	.147	.230	.331	.451	.589	.745	.920	1.113	1.325	1.804	2.356
4½"	.131	.204	.294	.401	.523	.663	.818	.990	1.178	1.603	2.094
5"	.118	.184	.265	.361	.471	.596	.736	.891	1.060	1.443	1.885
5½"	.107	.167	.240	.327	.428	.542	.669	.809	.963	1.311	1.712
6"	.098	.153	.221	.300	.392	.497	.613	.742	.883	1.202	1.571
6½"	.090	.141	.204	.277	.362	.458	.566	.685	.815	1.110	1.450
7"	.084	.131	.189	.257	.336	.426	.526	.636	.757	1.030	1.346
7½"	.078	.123	.176	.240	.314	.397	.491	.594	.707	.962	1.256
8"	.073	.115	.165	.225	.294	.373	.460	.557	.663	.902	1.178
9"	.066	.102	.146	.200	.262	.330	.405	.495	.590	.800	1.05
10"	.058	.091	.132	.180	.235	.297	.365	.445	.530	.720	.940
12"	.049	.076	.110	.150	.196	.248	.306	.371	.442	.601	.785
14"	.042	.065	.094	.128	.167	.212	.263	.318	.376	.515	.665
16"	.037	.057	.082	.112	.146	.185	.230	.277	.330	.450	.585

Tension in Rods.

TENSION PER FOOT WIDTH
TENSION @ 16000#□" 20000#□" 24000#□"

		1/4"	5/16"	3/8"	7/16"	1/2"
SPACING OF RODS IN INCHES	3"	3140 3926 4710	4909 6136 7363	7065 8832 10598	9619 12024 14429	12563 15704 18845
	3½"	2693 3366 4039	4206 5258 6310	6054 7568 9082	8243 10354 12465	10766 13458 16150
	4"	2357 2946 3535	3680 4601 5521	5299 6624 7949	7214 9018 10822	9422 11778 14134
	4½"	2094 2618 3142	3272 4090 4908	4710 5888 7066	6413 8016 9619	8374 10467 12563
	5"	1885 2356 2827	2944 3680 4416	4238 5298 6358	5771 7214 8657	7538 9422 11306
	5½"	1712 2140 2568	2675 3344 4013	3850 4812 5774	5241 6552 7862	6846 8558 10270
	6"	1570 1963 2355	2454 3068 3681	3533 4416 5299	4810 6012 7213	6282 7852 9422
	6½"	1450 1833 2216	2264 2830 3396	3259 4074 4889	4438 5548 6658	5797 7246 8695
	7"	1346 1683 2019	2103 2629 3155	3027 3784 4541	4122 5152 6182	5383 6729 8075
	7½"	1257 1571 1885	1963 2454 2945	2826 3532 4238	3846 4808 5770	5024 6280 7536
	8"	1178 1473 1767	1840 2300 2760	2650 3312 3974	3607 4508 5411	4711 5889 7067

Tension in Rods.

·TENSION PER FOOT WIDTH·

TENSION @ 16000#□" 20000#□" 24000#□"

		9/16"	5/8"	11/16"	3/4"	7/8"	1"
SPACING OF RODS IN INCHES	3"	15904	19635	23756	28275	38483	50266
		19880	24544	29696	35344	48104	62831
		23856	29453	35635	42413	57725	75397
	3½"	13629	16827	20358	24232	32979	43077
		17036	21034	25448	30289	41224	53846
		20443	25241	30537	36347	49469	64615
	4"	11928	14726	17817	21206	28862	37699
		14909	18408	22272	26508	36078	47124
		17890	22090	26726	31810	43294	56549
	4½"	10602	13089	15838	18990	25656	33510
		13253	16362	19798	23737	32070	41887
		15904	19634	23758	28484	38484	50264
	5"	9542	11780	14253	16965	23090	30158
		11928	14726	17816	21205	28862	37698
		14314	17671	21379	25446	34634	45238
	5½"	8667	10701	12947	15410	20973	27393
		10834	13775	16184	19262	26216	34242
		13001	16030	19421	23114	31459	41090
	6"	7952	9818	11878	14138	19242	25133
		9940	12272	14848	17672	24052	31416
		11928	14726	17818	21206	28862	37699
	6½"	7339	9061	10963	13048	17758	23197
		9174	11326	13704	16310	22198	28996
		11009	13591	16445	19572	26638	34795
	7"	6814	8413	10179	12116	16490	21538
		8518	10517	12724	15144	20612	26923
		10222	12620	15269	18173	24734	32307
	7½"	6362	7853	9502	11309	15392	20106
		7952	9816	11878	14136	19240	25132
		9542	11779	14254	16963	23088	30158
	8"	5964	7363	8909	10603	14430	18850
		7454	9204	11136	13254	18030	23562
		8945	11045	13363	15905	21647	28274

Weight of Rods.

WEIGHT OF STEEL IN POUNDS
PER SQUARE FOOT FOR RODS AND SPACING GIVEN

ROD DIAMETER

SPACING OF RODS IN INCHES	1/4"	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"	3/4"	7/8"	1"
3"	.666	1.044	1.50	2.044	2.667	3.38	4.172	5.048	6.008	8.176	10.68
3½"	.568	.895	1.287	1.755	2.287	2.897	3.576	4.327	5.15	7.008	9.154
4"	.500	.783	1.125	1.533	2.00	2.535	3.129	3.786	4.506	6.132	8.000
4½"	.444	.696	1.000	1.362	1.778	2.254	2.782	3.366	4.006	5.450	7.120
5"	.400	.626	.90	1.226	1.60	2.028	2.500	3.029	3.605	4.906	6.400
5½"	.364	.570	.818	1.115	1.455	1.825	2.275	2.753	3.277	4.412	5.821
6"	.333	.522	.750	1.022	1.333	1.690	2.086	2.524	3.004	4.088	5.34
6½"	.307	.482	.693	.944	1.231	1.561	1.925	2.330	2.780	3.732	4.929
7"	.285	.447	.643	.876	1.143	1.448	1.788	2.163	2.575	3.465	4.577
7½"	.266	.418	.600	.818	1.067	1.352	1.669	2.019	2.403	3.234	4.272
8"	.250	.392	.563	.767	1.000	1.268	1.565	1.893	2.253	3.066	4.000
9"	.222	.348	.500	.681	.889	1.127	1.391	1.683	2.003	2.725	3.560
10"	.200	.313	.450	.613	.800	1.014	1.251	1.519	1.803	2.453	3.200
12"	.167	.261	.375	.511	.667	.845	1.043	1.262	1.502	2.044	2.670
14"	.143	.224	.322	.438	.572	.724	.894	1.082	1.288	1.733	2.289
16"	.126	.196	.282	.384	.500	.634	.783	.947	1.127	1.533	2.000

Beam Reinforcement.

Beam reinforcement is shown for three types of beams, similar in their general character. The four-rod type of beam reinforcement shown upon page 64 is the simplest form and the one recommended for general use. For interior spans, the four rods composing the beam are exactly alike. The truss arrangement is formed by means of two of the rods having their bent portions turned each way in each beam. The shear in the beam is amply provided for by means of the tension rods, which extend to the top chord and continue over the point of support, and also by means of the shear loops, which are spaced on an average of twelve inches on centers throughout the length of the beam. By means of their interlocking with the spacing bar and slab rods, these shear loops thoroughly tie the floor slab to the beam and insure its action as a tee-section.

There is no ironclad rule to determine the depth of a beam so long as all stresses are cared for, but in general it ought to be assumed that the height of a beam, from the top of the slab to the extreme bottom of the concrete, is at least equal, in inches, to the span of the beam in feet.

The sizes of loops which should be used with beams of various heights are given in the table on page 75.

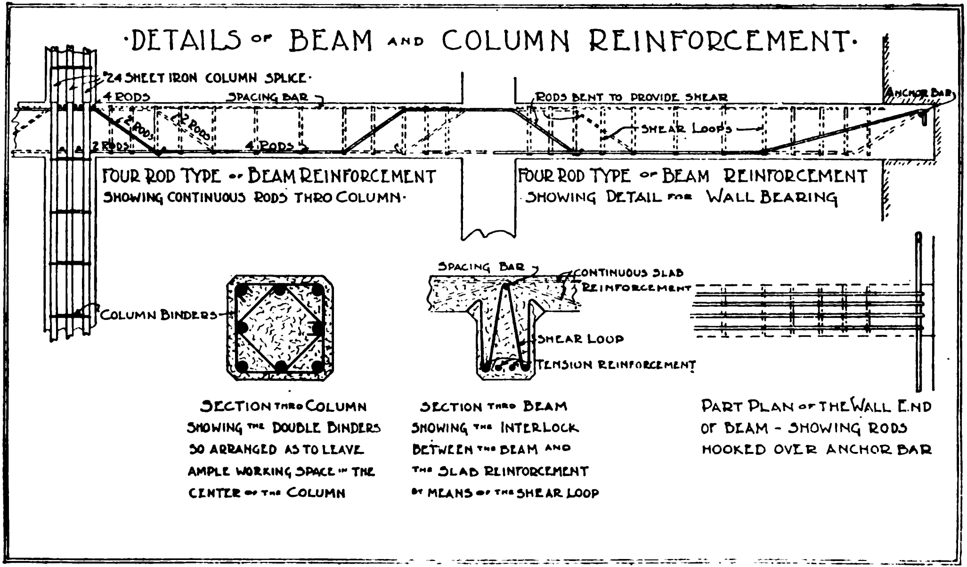
For end spans of beams a slightly different form of rod is shown.

The six-rod type of beam shown on page 65 is exactly like the four-rod type except that two straight rods in the lower portion of the beam have been added. This is merely a convenient way of increasing the strength of the four-rod type of beam.

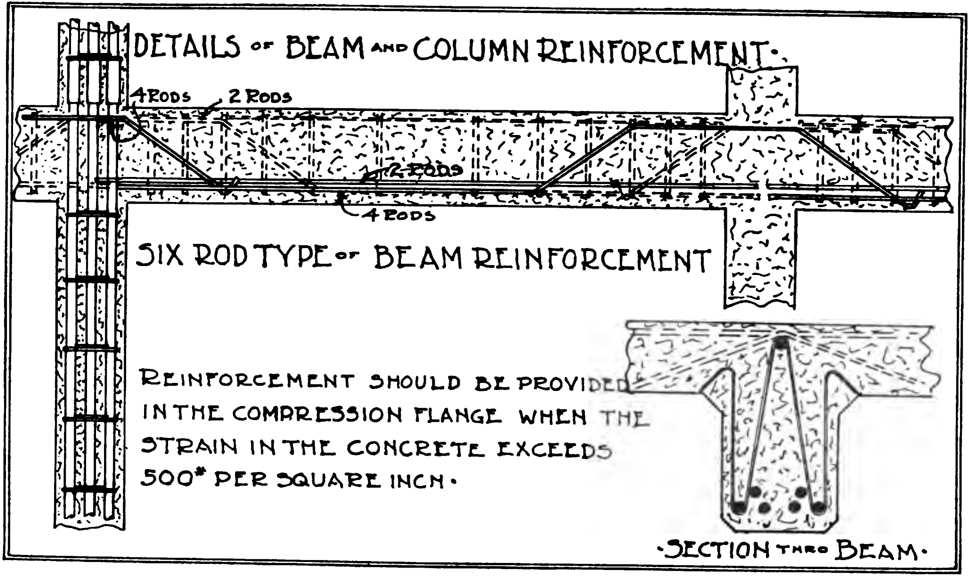
Care should be taken in designing these beams that they are not assumed so shallow that the compression flange of the beam, together with the assistance of the slab, is not sufficient to equal the tension in the rods used. To avoid this a deep beam should be assumed, if possible. If not, steel must be placed in the compression flange to give assistance to the concrete.

The eight-rod type of beam reinforcement is shown upon page 66. This type is used where exceedingly heavy girders are required, and especially where the shear in the girders is a maximum, the great number of rods passing up on the diagonal at each end, together with the horizontal ends of the rods at the bottom extending into the column, providing an abundance of shear. The designer should take into consideration the compression strains developed in the compression chord, and should also provide a beam of sufficient width to give room for the placing of the rods.

Four Rod Type.


·DETAILS OF BEAM AND COLUMN REINFORCEMENT·
#24 SHEET IRON COLUMN SPLICE·
4 RODS
SPACING BAR
2 RODS
2 RODS
2 RODS
4 RODS
FOUR ROD TYPE OF BEAM REINFORCEMENT SHOWING CONTINUOUS RODS THRO COLUMN·
RODS BENT TO PROVIDE SHEAR
SHEAR LOOPS
ANCHOR BAR
FOUR ROD TYPE OF BEAM REINFORCEMENT ·SHOWING DETAIL FOR WALL BEARING
COLUMN BINDERS
SPACING BAR
CONTINUOUS SLAB REINFORCEMENT
SHEAR LOOP
TENSION REINFORCEMENT
SECTION THRO COLUMN SHOWING THE DOUBLE BINDERS SO ARRANGED AS TO LEAVE AMPLE WORKING SPACE IN THE CENTER OF THE COLUMN
SECTION THRO BEAM SHOWING THE INTERLOCK BETWEEN THE BEAM AND THE SLAB REINFORCEMENT BY MEANS OF THE SHEAR LOOP
PART PLAN OF THE WALL END OF BEAM - SHOWING RODS HOOKED OVER ANCHOR BAR

Six Rod Type.



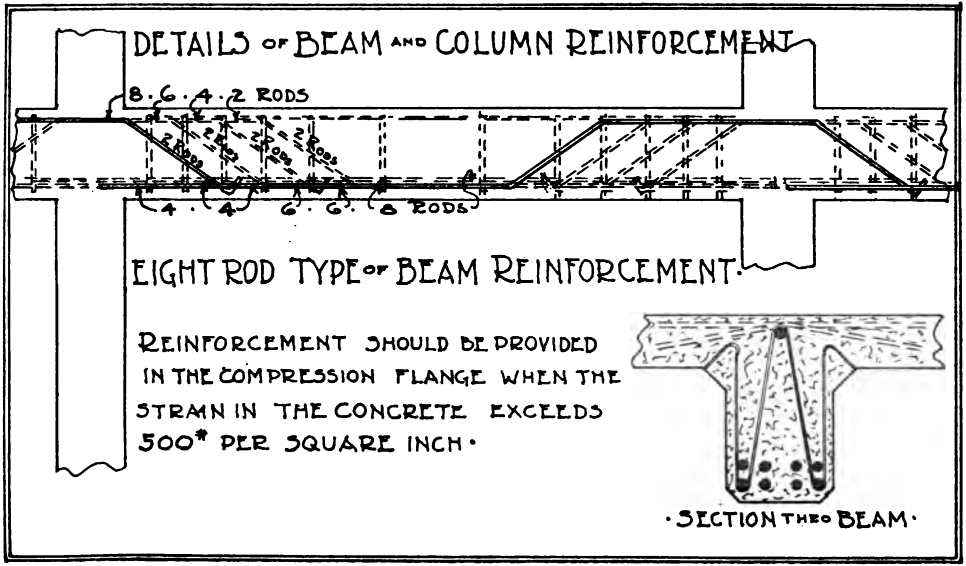
DETAILS OF BEAM AND COLUMN REINFORCEMENT.

SIX ROD TYPE OF BEAM REINFORCEMENT

REINFORCEMENT SHOULD BE PROVIDED IN THE COMPRESSION FLANGE WHEN THE STRAIN IN THE CONCRETE EXCEEDS 500* PER SQUARE INCH.

·SECTION THRO BEAM·

Eight Rod Type.



DETAILS OF BEAM AND COLUMN REINFORCEMENT

EIGHT ROD TYPE OF BEAM REINFORCEMENT·

REINFORCEMENT SHOULD BE PROVIDED IN THE COMPRESSION FLANGE WHEN THE STRAIN IN THE CONCRETE EXCEEDS 500* PER SQUARE INCH·

·SECTION THRO BEAM·

Bending Moment in Beams.

The bending moment in uniformly loaded beams for simple spans from 5 feet to 50 feet long, and for total live plus dead loads of from 5,000 pounds to 100,000 pounds is given in the tables on pages 68, and 70. These tables of bending moment are to be used in connection with the moment of resistance tables for beams, given upon pages 72, and 74 It is understood that the moment of resistance in any beam must always exceed the bending moment given in these tables.

Example: What is the bending moment in foot pounds in a beam of 16-foot span under a total uniform load of 35,000 pounds? Answer: 70,000 foot pounds.

Example: What reinforced concrete beam will resist this bending moment of 70,000 foot pounds? Answer: From page 72 a beam of the standard four-rod type having a total depth of 22″ and four 1″ rods for reinforcement will give a moment of resistance of 70,000 foot pounds. If a shallower beam is required, one of 18″ depth and having four 1⅛″ rods will give the required moment of resistance.

For beams having concentrated loads the bending moment must be calculated by the usual methods, as explained in text books on mechanics.

Bending Moment in Beams.

BENDING MOMENT IN FOOT POUNDS
IN SIMPLE BEAMS — $M = \frac{1}{8}WL$

SPAN	UNIFORM LOAD IN POUNDS — DEAD + LIVE						
	5000	6000	7000	8000	9000	10000	15000
5'	3100	3800	4400	5000	5600	6300	9400
6'	3800	4500	5300	6000	6700	7500	11300
7'	4400	5300	6200	7000	7900	8800	13200
8'	5000	6000	7000	8000	9000	10000	15000
9'	5600	6800	7900	9000	10200	11200	17000
10'	6200	7500	8800	10000	11200	12500	18700
11'	6900	8200	9600	11000	12300	13200	20500
12'	7500	9000	10500	12000	13500	15000	22500
13'	8200	9800	11500	13000	14700	16200	24500
14'	8800	10500	12300	14000	15700	17500	26200
15'	9400	11200	13200	15000	17000	18700	28000
16'	10000	12000	14000	16000	18000	20000	30000
17'	10600	12700	15000	17000	19000	21200	32000
18'	11300	13500	15700	18000	20200	22500	34000
19'	11700	14200	16600	19000	21400	23700	35500
20'	12500	15000	17500	20000	22500	25000	37500
21'		15700	18300	21000	23000	26000	39500
22'		16500	19200	22000	24500	27500	41000
23'			20000	23000	25700	28700	43000
24'			21000	24000	27000	30000	45000
26'				26000	29300	32500	49000
28'				28000	31500	35000	52500
30'					33800	37500	56000
35'						44000	66000
40'							75000
45'							
50'							

Bending Moment in Beams.

BENDING MOMENT IN FOOT POUNDS IN SIMPLE BEAMS $M \cdot \frac{1}{8} WL$

SPAN	UNIFORM LOAD IN POUNDS - LIVE + DEAD.					
	20000#	25000#	30000#	35000#	40000#	45000#
5'	12500	15600	18800			
6'	15000	18800	22500			
7'	17500	22000	26200	31000		
8'	20000	25000	30000	35000		
9'	22500	28000	34000	39000	45000	
10'	25000	31000	37500	43500	50000	56000
11'	27500	34000	41000	48000	55000	62000
12'	30000	37500	45000	52500	60000	68000
13'	32500	41000	49000	57000	65000	73000
14'	35000	44000	53000	61000	70000	78000
15'	37500	47000	56000	66000	75000	84000
16'	40000	50000	60000	70000	80000	90000
17'	42500	53000	64000	74000	85000	96000
18'	45000	56000	68000	79000	90000	102000
19'	47500	59000	71000	83000	95000	107000
20'	50000	62500	75000	87500	100000	112500
21'	52500	66000	79000	92000	105000	118000
22'	55000	69000	83000	96000	110000	124000
23'	57500	72000	86000	100000	115000	128000
24'	60000	75000	90000	105000	120000	135000
26'	65000	81000	98000	114000	130000	147000
28'	70000	87000	105000	122000	140000	157000
30'	75000	94000	113000	131000	150000	168000
35'	88000	110000	130000	152000	175000	196000
40'	100000	125000	150000	175000	200000	225000
45'	113000	140000	168000	196000	225000	252000
50'	125000	156000	187000	220000	250000	280000

Bending Moment in Beams.

BENDING MOMENT IN FOOT POUNDS IN SIMPLE BEAMS - $M = \frac{1}{8} WL$

SPAN	UNIFORM LOAD IN POUNDS .. LIVE + DEAD					
	50000#	60000#	70000#	80000#	90000#	100000#
10'	62000	75000				
11'	69000	83000	97000	110000		
12'	75000	90000	105000	120000	135000	150000
13'	81000	98000	115000	130000	146000	162000
14'	88000	105000	122000	140000	158000	175000
15'	94000	113000	132000	150000	170000	187000
16'	100000	120000	140000	160000	180000	200000
17'	107000	127000	150000	170000	192000	213000
18'	113000	135000	157000	180000	203000	225000
19'	118000	142000	166000	190000	213000	237000
20'	125000	150000	175000	200000	225000	250000
21'	131000	157000	184000	210000	235000	262000
22'	137000	165000	192000	220000	246000	275000
23'	143000	172000	200000	230000	257000	286000
24'	150000	180000	210000	240000	270000	300000
26'	162000	194000	227000	260000	292000	325000
28'	175000	210000	244000	280000	312000	350000
30'	187000	225000	261000	300000	335000	375000
35'	218000	262000	305000	350000	390000	435000
40'	250000	300000	350000	400000	450000	500000
45'	280000	336000	392000	450000	505000	560000
50'	312000	375000	435000	500000	560000	625000

Moment of Resistance in Beams.

The tables on pages 72, and 74, give the moment of resistance in foot pounds, for beams from 10″ to 36″ in depth, and containing rods from ½″ to 1¼″ in diameter, and of the four-rod, six-rod and eight-rod types, illustrated on pages 64, and 66. These tables may be used either in connection with the bending moment in beams having concentrated or uniform loads.

Example: If a beam is to be 20″ in depth and must have a moment of resistance of 49,000 foot pounds, what size rods will be required? Answer: Four ⅞″ rods. The table also indicates that the tension area of the four ⅞″ rods is 2.405 square inches, that the tension value of these rods at 16,000 pounds per square inch is 38,800 pounds and that the effective depth in a 20″ beam is 1.27 feet. The effective depth means the distance from the center of tension to the center of compression.

In connection with these beams of the four, six, and eight-rod types, loops must be provided of various sizes according to the depth of the beam. The table on page 75 indicates the size of the loops, together with the length of the pieces and the weight required for various heights of beams. It is usual to space these loops closer at the ends of the beam than at the center, but on an average there should be a loop for each foot of length. The estimator will note that the fourth column, which gives the weight of the loop, will also give the weight of loops per lineal foot of beam if the above rule is followed, and in estimating, if the lineal feet of beam are taken, the weight of the loops required is readily calculated.

Four-Rod Type of Beams.

MOMENT OF RESISTANCE

· IN FOOT POUNDS ·

ROUND RODS			4-½"	4-⅝"	4-¾"	4-⅞"	4-1"	4-1⅛"
TOTAL AREA OF RODS			.7854□"	1.227□"	1.767□"	2.405□"	3.1416□"	3.976□"
TENSION VALUE @ 16000 #□"			12500#	20300#	28300#	38800#	50000#	64000#
· HEIGHT OF BEAM & EFFECTIVE DEPTH ·	10"	.56'	7000	11400	15800	21700		
	11"	.64'	8000	13000	18000	24700	-	
	12"	.71'	8850	14400	20000	27500	35500	
	13"	.78'	9700	15800	22000	30000	39000	
	14"	.85'	10600	17300	24000	33000	42500	54500
	15"	.92'	11500	18600	26000	35500	46500	58500
	16"	.99'	12400	20100	28000	38500	50000	64000
	17"	1.06'	13200	21600	30000	41000	53000	68000
	18"	1 13'	14000	23000	32000	44000	56500	73000
	19"	1.20'	15000	24400	34000	46500	60000	77000
	20"	1.27'	15800	26000	36000	49500	63500	81000
	21"	1.34'		27000	37800	52000	67000	86000
	22"	1.40'		28300	39500	54000	70000	89000
	23"	1.48'			42000	57500	74000	95000
	24"	1.55'			43500	60000	77500	99000
	25"	1.62'			45500	62500	81000	104000

Six-Rod Type of Beams.

MOMENT OF RESISTANCE IN FOOT POUNDS

ROUND RODS			6-5/8"	6-3/4"	6-7/8"	6-1"	6-1 1/8"	6-1 1/4"
TOTAL AREA OF RODS			1.8408□"	2.6508□"	3.6078□"	4.7124□"	5.964□"	7.3632□"
TENSILE VALUE @ 16000#□"			29400#	42400#	57700#	75400#	95400#	117800#
HEIGHT OF BEAM & EFFECTIVE DEPTH	15"	.92'	27000	39000	53100			
	16"	.99'	29100	42000	57100			
	17"	1.06'	31100	45000	61200	80000		
	18"	1.13'	33200	48000	65200	85200		
	19"	1.20'	35300	50900	69200	90500	115000	
	20"	1.27'	37300	53900	73200	95700	121000	
	21"	1.34'	39400	56800	77300	101000	128000	158000
	22"	1.40'	41200	59400	80800	105500	133000	165000
	23"	1.48'	43500	62700	85400	111600	141000	174000
	24"	1.55'	45600	65720	89500	116800	148000	182600
	25"	1.62'		68700	93500	122000	155000	191000
	26"	1.69'		71600	97500	127400	161200	199000
	27"	1.76'			101500	132700	168000	207000
	28"	1.83'			105600	138000	174500	216000
	29"	1.90'				143300	181000	224000
	30"	1.97'				148000	188000	232000

Eight-Rod Type of Beams.

MOMENT OF RESISTANCE
·IN FOOT POUNDS·

ROUND RODS		$8-\frac{5}{8}$"	$8-\frac{3}{4}$"	$8-\frac{7}{8}$"	8-1"	$8-1\frac{1}{8}$"	$8-1\frac{1}{4}$"
TOTAL AREA OF RODS		2.454□"	3.534□"	4.810□"	6.283□"	7.952□"	9.818□"
TENSILE VALUE @ 16000#□"		39200	56500	77000	100500	127000	157000
·HEIGHT OF BEAM & EFFECTIVE DEPTH·							
21"	1.34'	52500	75700	103200			
22"	1.40'	55000	79100	107800	140700		
23"	1.48'	58000	83600	114000	148700		
24"	1.55'	60700	87500	119300	155800	197000	
25"	1.62'	63500	91500	124700	162800	205700	
26"	1.69'	66300	95500	130100	170000	214600	265300
27"	1.76'	69000	99500	135500	176900	223500	276300
28"	1.83'	71700	103400	140900	183900	232400	287300
29"	1.90'		108200	146300	191000	241300	298300
30"	1.97'		111300	151700	198000	250200	309300
31"	2.04'		115300	157000	205000	259000	320000
32"	2.10'		118700	161700	211000	266700	330000
33"	2.17'			167000	218000	275600	340700
34"	2.26'			174000	227100	287000	354800
35"	2.35'			181000	236200	298500	369000
36"	2.40'			184800	241000	304800	376800

Shear Loops for Beams.

·SHEAR LOOPS			
	SIZE	LENGTH	WEIGHT·
TOTAL HEIGHT OF BEAM TO TOP OF SLAB	SIZE OF BAR FROM WHICH LOOP IS MADE	LENGTH REQD TO MAKE ONE LOOP	WEIGHT OF ONE LOOP
10"	$\frac{3}{4}$" × $\frac{1}{8}$"	2'-10"	0.92#
11"	"	3'-2"	1.02#
12"	"	3'-6"	1.12#
13"	"	3'-10"	1.24#
14"	"	4'-2"	1.34#
15"	"	4'-6"	1.44#
16"	1" × $\frac{1}{8}$"	4'-10"	2.07#
17"	"	5'-2"	2.21#
18"	"	5'-6"	2.34#
19"	"	5'-10"	2.47#
20"	"	6'-2"	2.62#
21"	"	6'-6"	2.76#
22"	"	6'-10"	2.90#
23"	"	7'-2"	3.04#
24"	"	7'-6"	3.19#
25"	"	7'-10"	3.33#
26"	"	8'-2"	3.47#
27"	"	8'-6"	3.62#
28"	"	8'-10"	3.76#
29"	"	9'-2"	3.90#
30"	1$\frac{1}{2}$" × $\frac{1}{8}$"	9'-6"	6.08#
31"	"	9'-10"	6.29#
32"	"	10'-2"	6.50#
33"	"	10'-6"	6.72#
34"	"	10'-10"	6.93#
35"	"	11'-2"	7.14#
36"	"	11'-6"	7.36#

Columns.

From pages 78 to 85 are given the capacities of reinforced concrete columns ranging in size from 10"x10" over all dimensions, to 24"x24", all the different sizes of columns having the sizes of rods practical to be used, the area of the steel corresponding to the rods, the weight of rods per lineal foot of column, the maximum height at which the column should be used for its full capacity, and the full capacity of the column under the conditions stated.

In these columns the net cross-sectional area of the concrete, with the exception of one inch around its perimeter, has been calculated at 350 pounds per square inch direct compression. The steel rods have been calculated at a compressive value of 12,000 pounds per square inch.

It is considered that in a concrete column for the sake of economy, the outside dimensions will be the same from the bottom to the top of the building, and that the concrete with the exception of a slight difference in net area will carry the same amount of load, but that the rods will change in size as the total load changes, the steel being added in sufficient amount to give the total required capacity at the unit stresses already given.

It will be noticed that no attempt has been made to keep the proper ratio of the modulae of elasticity of the concrete and the steel. If the ratio was assumed to be 12, and the concrete pressure kept at the point usually assumed, the steel would be necessarily figured at so low a value as to make the use of the column prohibitive on account of its expense.

Some authorities recommend stressing the concrete on the diameters here given, to as high as 700 pounds per square inch. It will be found in the majority of cases of the columns herein given, that if the test were applied as to the ratio of the modulae of elasticity being 12, that the concrete is not stressed beyond 700 pounds per square inch, and it will be found in the same columns, that if the value is assumed 700 pounds per square inch on the concrete, that the steel pressure is extremely low, which puts the columns on a most conservative basis.

On the other hand, in those columns where because of the ratio of 12, the concrete is apparently stressed beyond the safe point, it will be found invariably, that the steel might be assumed to carry the entire load, without assistance from the concrete, without being stressed to more than 13,000 pounds or 14,000 per square inch, which is abundantly safe in itself.

Regardless of what the modulae of elasticity may be, the columns as given here are considered by many engineers to be extremely conservative, and have given satisfaction in some of the most prominent concrete buildings in the United States.

Concrete for use in columns should be mixed in the proportions of one part of portland cement, to two parts of sand, to four parts of hazelnut stones.

Column reinforcement is shown on pages 64 to 65 in connection with the four-rod type of beam. A section through the column shows how the binders which are formed of round rods are placed about the vertical column rods to form a tie. The principal advantage in this form of binders is that it provides a space down the center of the column for the placing of the concrete, and for the puddling required to bring the cement in close contact with the steel.

Ten Inch Column.

COLUMN 10"×10'

CONCRETE @ 350#□"   STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
No.	DIA.	TOTAL AREA	TOTAL WT. PER FOOT	
4	3/4"	1.76□"	6.01#	10' 42000#
4	7/8"	2.40□"	8.18#	10' 52000#
4	1"	3.14□"	10.68#	12' 58000#
4	1 1/8"	3.97□"	13.52#	14' 68000#
4	1 1/4"	4.90□"	16.69#	16' 79000#
4	1 3/8"	5.94□"	20.19#	16' 91000#
4	1 1/2"	7.06□"	24.03#	18' 104000#
4	1 5/8"	8.29□"	28.20#	18' 117000#
4	1 3/4"	9.62□"	32.71#	18' 134000#
4	1 7/8"	11.04□"	37.55#	18' 149000#
	2"	12.56□"	42.72#	18' 167000#

Twelve Inch Column.

COLUMN 12"×12"

CONCRETE @ 350#□" STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
No.	DIA.	TOTAL AREA	TOTAL WT PER FOOT	
8	3/4"	3.53□"	12.02#	12' 75000#
8	7/8"	4.81□"	16.35#	16' 90000#
8	1"	6.28□"	21.36#	20' 107000
8	1 1/8"	7.95□"	27.03#	22' 127000#
8	1 1/4"	9.81□"	33.38#	22' 149000#
8	1 3/8"	11.88□"	40.38#	22' 173000#
8	1 1/2"	14.13□"	48.06#	22' 199000#
8	1 5/8"	16.59□"	56.41#	22' 225000#
8	1 3/4"	19.24□"	65.42#	22' 259000#
8	1 7/8"	22.08□"	75.10#	22' 290000#
8	2"	25.13□"	85.44#	22' 325000#

Fourteen Inch Column.

COLUMN 14"×14"

CONCRETE @ 350#□" STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
NO	DIA	TOTAL AREA	TOTAL WT. PER FT.	
8	3/4"	3.53□"	12.02#	14' 90000#
8	7/8"	4.81□"	16.35#	14' 105000#
8	1"	6.28□"	21.36#	16' 122000#
8	1 1/8"	7.95□"	27.03#	18' 142000#
8	1 1/4"	9.81□"	33.38#	20' 164000#
8	1 3/8"	11.88□"	40.38#	22' 188000#
8	1 1/2"	14.13□"	48.06#	24' 214000#
8	1 5/8"	16.59□"	56.41#	24' 240000#
8	1 3/4"	19.24□"	65.42#	24' 274000#
8	1 7/8"	22.04□"	75.10#	24' 305000#
8	2"	25.13□"	85.44#	24' 340000#
8	2 1/8"	28.37□"	96.48#	24' 388000#
8	2 1/4"	31.81□"	108.16#	24' 420000#
8	2 3/8"	35.44□"	120.56#	24' 460000#
8	2 1/2"	39.26□"	133.52#	24' 504000#
8	2 5/8"	43.28□"	147.20#	24' 550000#
8	2 3/4"	47.52□"	161.60#	24' 600000#
8	2 7/8"	51.92□"	176.56#	24' 650000#

Sixteen Inch Column.

COLUMN 16" × 16"

CONCRETE @ 350#□" STEEL @ 12000#□"

Round Rods				Safe Load for Columns at Height Given	
No.	Dia.	Total Area	Total Wt. per Ft.		
8	7/8"	4.81□"	16.35#	16'	123000#
8	1"	6.28□"	21.36#	18'	140000#
8	1 1/8"	7.95□"	27.03#	20'	160000
8	1 1/4"	9.81□"	33.38#	24'	182000#
8	1 3/8"	11.88□"	40.38#	26'	206000#
8	1 1/2"	14.13□"	48.06#	30'	232000#
8	1 5/8"	16.59□"	56.41#	30'	258000#
8	1 3/4"	19.24□"	65.42#	30'	292000#
8	1 7/8"	22.04□"	75.10#	30'	323000#
8	2"	25.13□"	85.44#	30'	358000#
8	2 1/8"	28.37□"	96.48#	30'	406000#
8	2 1/4"	31.81□"	108.16#	30'	438000#
8	2 3/8"	35.44□"	120.56#	30'	478000#
8	2 1/2"	39.26□"	133.52#	30'	522000#
8	2 5/8"	43.28□"	147.20#	30'	568000#
8	2 3/4"	47.52□"	161.60#	30'	618000#
8	2 7/8"	51.92□"	176.56#	30'	668000#
8	3"	56.54□"	192.24#	30'	722000#
8	3 1/8"	61.36□"	208.64#	30'	778000#
8	3 1/4"	66.36□"	225.60#	30'	838000#

Eighteen Inch Column.

COLUMN 18"×18"				
CONCRETE @ 350#□"			STEEL @ 12000#□"	
ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
No.	DIA	TOTAL AREA	TOTAL WT. PER FT	
8	1"	6.28□"	21.36#	18' 162000#
8	1 1/8"	7.95□"	27.03#	20' 182000#
8	1 1/4"	9.81□"	33.38#	26' 204000#
8	1 3/8"	11.88□"	40.38#	28' 228000#
8	1 1/2"	14.13□"	48.06#	30' 254000#
8	1 5/8"	16.59□"	56.41#	32' 280000#
8	1 3/4"	19.24□"	65.42#	34' 314000#
8	1 7/8"	22.04□"	75.10#	36' 345000#
8	2"	25.13□"	85.44#	36' 380000#
8	2 1/8"	28.37□"	96.48#	36' 428000#
8	2 1/4"	31.81□"	108.16#	36' 460000#
8	2 3/8"	35.44□"	120.56#	36' 500000#
8	2 1/2"	39.26□"	133.52#	36' 544000#
8	2 5/8"	43.28□"	147.20#	36' 590000#
8	2 3/4"	47.52□"	161.60#	36' 640000#
8	2 7/8"	51.92□"	176.56#	36' 690000#
8	3"	56.54□"	192.24#	36' 744000#
8	3 1/8"	61.36□"	208.64#	36' 800000#
8	3 1/4"	66.36□"	225.60#	36' 860000#
8	3 1/2"	76.96□"	261.68#	36' 980000#

Twenty Inch Column.

COLUMN 20"×20"

CONCRETE @ 350#□" STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
NO.	DIA	TOTAL AREA	TOTAL WT PER FT	
8	1¼"	9.81□"	33.38#	26' 227000#
8	1⅜"	11.88□"	40.38#	28' 251000#
8	1½"	14.13□"	48.06#	32' 277000#
8	1⅝"	16.59□"	56.41#	34' 303000#
8	1¾"	19.24□"	65.42#	36' 337000#
8	1⅞"	22.04□"	75.10#	38' 368000#
8	2"	25.13□"	85.44#	40' 403000#
8	2⅛"	28.37□"	96.48#	40' 451000#
8	2¼"	31.81□"	108.16#	40' 483000#
8	2⅜"	35.44□"	120.56#	40' 523000#
8	2½"	39.26□"	133.52#	40' 567000#
8	2⅝"	43.28□"	147.20#	40' 613000#
8	2¾"	47.52□"	161.60#	40' 663000#
8	2⅞"	51.92□"	176.56#	40' 713000#
8	3"	56.54□"	192.24#	40' 767000#
8	3⅛"	61.36□"	208.64#	40' 823000#
8	3¼"	66.36□"	225.60#	40' 883000#
8	3½"	76.96□"	261.68#	40' 1003000#
8	3¾"	88.32□"	300.48#	40' 1143000#
8	4"	100.52□"	341.84#	40 1273000#

Twenty-two Inch Column.

COLUMN 22"×22"

CONCRETE @ 350#□" STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
No.	DIA.	TOTAL AREA	TOTAL WT. PER FT.	
8	1¼"	9.81□"	33.38#	26' 254000#
8	1⅜"	11.88□"	40.38#	28' 278000#
8	1½"	14.13□"	48.06#	32' 304000#
8	1⅝"	16.59□"	56.41#	36' 330000#
8	1¾"	19.24□"	65.42#	38' 364000#
8	1⅞"	22.04□"	75.10#	42' 395000#
8	2"	25.13□"	85.44#	42' 430000#
8	2⅛"	28.37□"	96.48#	42' 478000#
8	2¼"	31.81□"	108.16#	42' 510000#
8	2⅜"	35.44□"	120.56#	42' 550000#
8	2½"	39.26□"	133.52#	42' 594000#
8	2⅝"	43.28□"	147.20#	42' 640000#
8	2¾"	47.52□"	161.60#	42' 690000#
8	2⅞"	51.92□"	176.56#	42' 740000#
8	3"	56.54□"	192.24□"	42' 794000#
8	3⅛"	61.36□"	208.64#	42' 850000#
8	3¼"	66.36□"	225.60#	42' 910000#
8	3½"	76.96□"	261.68#	42' 1030000#
8	3¾"	88.32□"	300.48#	42 1170000#
8	4"	100.52□"	341.84#	42' 1300000#

Twenty-four Inch Column.

COLUMN 24"×24"

CONCRETE @ 350#□" STEEL @ 12000#□"

ROUND RODS				SAFE LOAD FOR COLUMNS AT HEIGHT GIVEN
NO.	DIA	TOTAL AREA	TOTAL WT. PER FT.	
8	1¼"	9.81□"	33.38#	28' 279000#
8	1⅜"	11.88□"	40.38#	30' 303000#
8	1½"	14.13□"	48.06#	34' 329000#
8	1⅝"	16.59□"	56.41#	38' 355000#
8	1¾"	19.24□"	65.42#	40' 389000#
8	1⅞"	22.04□"	75.10#	44' 420000#
8	2"	25.13□"	85.44#	44' 455000#
8	2⅛"	28.37□"	96.48#	44' 503000#
8	2¼"	31.81□"	108.16#	44' 535000#
8	2⅜"	3544□"	120.56#	44' 575000#
8	2½"	39.26□"	133.52#	44' 619000#
8	2⅝"	43.28□"	147.20#	44' 665000#
8	2¾"	47.52□"	161.60#	44' 715000#
8	2⅞"	51.92□"	176.56#	44' 765000#
8	3"	56.54□"	192.24#	44' 819000#
8	3⅛"	61.36□"	208.64#	44' 875000#
8	3¼"	66.36□"	225.60#	44' 935000#
8	3½"	76.96□"	261.68#	44' 1055000#
8	3¾"	88.32□"	300.48#	44' 1195000#
8	4"	100.52□"	341.84#	44' 1325000#

Column Binders.

Column binders, regardless of the size of the column or the capacity therein should be of the sizes given in the accompanying table on page 87, and in all cases the binders should be spaced 12″ on centers. The table gives the size of the column together with the size of the binder, and the length of the pieces from which it is made in feet and inches, and its total weight in pounds. These binders are based upon the detail given upon page 64, and it will be noticed that for columns larger than 10″x10″ where eight rods are used, each binder consists of two pieces, the one set on the diagonal, as shown. The binders being spaced just one foot on centers, the weight of the binders given in the table is convenient for estimating purposes, being the weight per lineal foot of column.

Column Binders.

·COLUMN BINDERS·

·SIZE -LENGTH- WEIGHT·

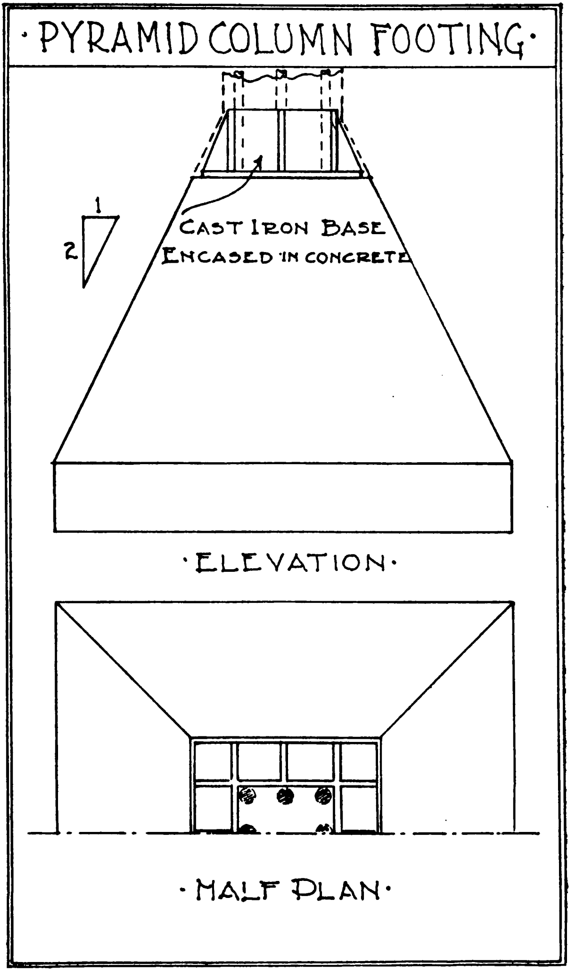
SIZE OF COLUMN	SIZE OF RODS FROM WHICH BINDERS ARE MADE	LENGTHS OF THE TWO PIECES REQ'D FOR ONE COMPLETE BINDER	TOTAL WEIGHT OF ONE COMPLETE BINDER
10"×10"	$\frac{3}{8}$"	3'-2"	1.20#
12"×12"	$\frac{7}{16}$"	2'-3" 3'-10"	3.1#
14"×14"	$\frac{7}{16}$"	3'-6" 4'-6"	4.1#
16"×16"	$\frac{7}{16}$"	4'-0" 5'-2"	4.68#
18"×18"	$\frac{7}{16}$"	4'-6" 5'-10"	5.28#
20"×20"	$\frac{1}{2}$"	5'-0" 6'-6"	7.66#
22"×22"	$\frac{1}{2}$"	5'-6" 7'-2"	8.44#
24"×24"	$\frac{1}{2}$"	6'-0" 8'-0"	9.34#

Footings.

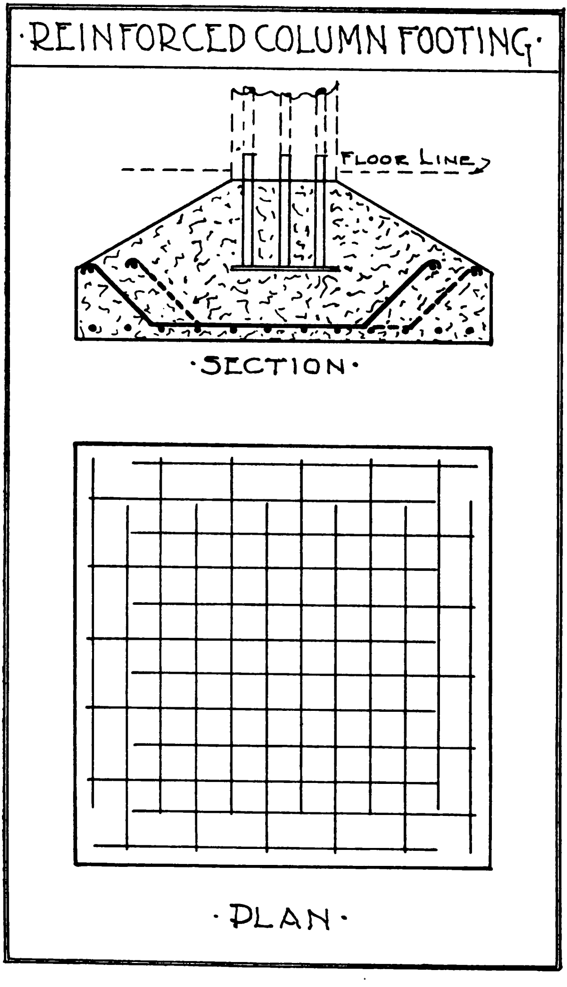
A reinforced spread footing is one in which the reinforcement is used to give the footing a great spread at a shallow depth. The reinforcement should be always arranged to take care of the shear in the concrete, similar to that shown in the detail. The column is given a bearing on these footings, by a steel plate within the footing and short pieces of steel of the same diameter as the column, being of steel of the same diameter as the column rods, being ptovided in such a way teat the column may be conveniently started, a splice being formed the same as at any floor level above.

Footings of the pyramid type do not require reinforcement, as the concrete is of such form as to furnish enough tension within itself. Usually footings of this character are supplied with cast iron base plates underneath the columns. This base plate is most conveniently formed of the box type in which the steel rods are extended to the bottom plate of the cast iron base.

Footing.


·PYRAMID COLUMN FOOTING·
1
2
CAST IRON BASE
ENCASED IN CONCRETE
·ELEVATION·
·HALF PLAN·

Footing.

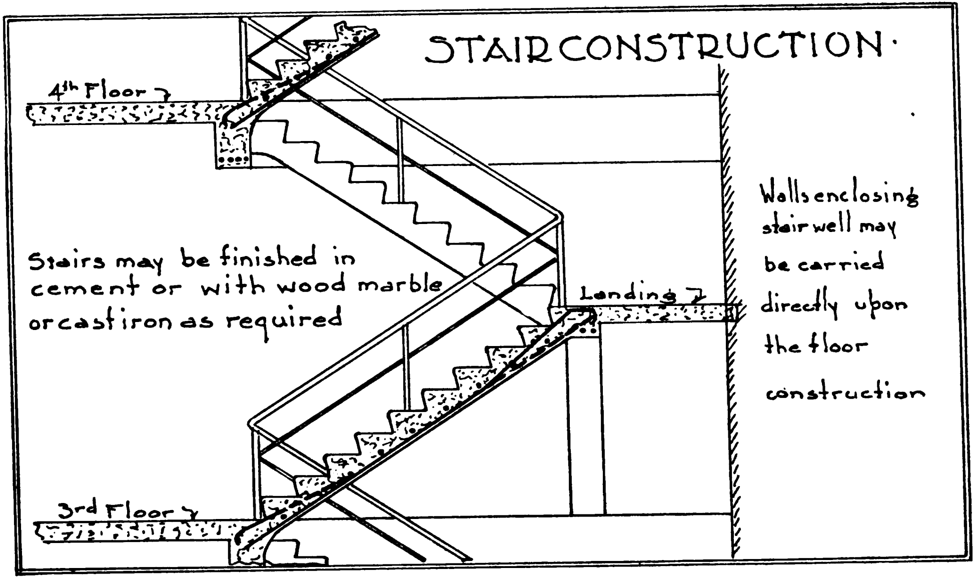


Stairs.

Stairs in reinforced concrete are economical and the most thoroughly fireproof type of stair construction possible. They may be finished on top either with a cement finish, or merely the structural portions of the stair may be built in concrete, and the top finished with marble, mosaic, cast iron, or other material suitable to the architectural requirements.

The type of stairs here detailed is that where stringers are not used but the treads are built directly upon a slab. This method is entirely satisfactory for short spans. Where the span becomes so great that the dead load of the stairs plus the live load requires a very thick slab, a stringer should be built at each side, the treads spanning between and acting as beams. The stringers are calculated the same as beams, the details being suited to resist the shear produced at the various angles.

Reinforced Concrete Stairs.


STAIR CONSTRUCTION.
4th Floor
Landing
3rd Floor
Stairs may be finished in cement or with wood marble or cast iron as required
Walls enclosing stair well may be carried directly upon the floor construction

Adhesion of Concrete to Rods.

Tests show that plain rods imbedded in concrete will develop an ultimate adhesion of something over 200 pounds per square inch. It is considered in good practice that 50 pounds per square inch is safe. In case the rods should be imbedded with a hook on the end or in a curved form, because of the increased friction, far more than 50 pounds to the square inch would be developed. In the case of heavy rods imbedded as tension members, care should be taken that a sufficient length of bar is imbedded in the concrete to develop the strength of the rod itself at the strain for which it is calculated.

The table on page 94 indicates the length of rods of various diameters imbedded in concrete, so that when the adhesion equals 50 pounds per square inch of surface, the strength of the rod will be fully developed, the fibre strains being calculated at 16,000 pounds, 20,000 pounds and 24,000 pounds per square inch.

Adhesion of Concrete to Rods.

REQUIRED LENGTH OF STRAIGHT RODS
IMBEDDED TO DEVELOP FIBRE STRAINS
GIVEN-ADHESION BEING 50# PER SQ. IN.

FIBRE STRAIN IN RODS		16000#□"	20000#□"	24000#□"
·DIAMETER OF ROUND RODS·	1/4"	1'-8"	2'-1"	2'-6"
	5/16"	2'-1"	2'-8"	3'-2"
	3/8"	2'-6"	3'-2"	3'-9"
	7/16"	2'-11"	3'-8"	4'-5"
	1/2"	3'-4"	4'-2"	5'-0"
	9/16"	3'-9"	4'-8"	5'-8"
	5/8"	4'-2"	5'-3"	6'-3"
	3/4"	5'-0"	6'-3"	7'-6"
	7/8"	5'-10"	7'-4"	8'-9"
	1"	6'-8"	8'-4"	10'-0"
	1 1/8"	7'-6"	9'-5"	11'-3"
	1 1/4"	8'-4"	10'-5"	12'-6"
	1 3/8"	9'-2"		
	1 1/2"	10'-0"		
	1 5/8"	10'-10"		
	1 3/4"	11'-8"		
	1 7/8"	12'-6"		
	2"	13'-4"		

Lumber for Forms.

On page 101 is given a method of building forms which are entirely collapsible, and which have been used extensively in the construction of buildings. This method of construction has proved extremely satisfactory because of its economy. The use of the 2″ solid plank may seem superfluous but in the end it is the cheapest way, because the 2″ plank will hold its position without being nailed, where a ⅞″ board would warp or would be broken by the handling of the material on top of it. Furthermore, heavy forms will have more salvage in them than light ones, coming out almost without damage. Forms should be figured to be used from two to four times, depending upon the size of the building. Usually if time permits, it is possible to use the forms three times in a 9-story building. Weather being suitable, forms may be removed in 20 days.

Setting of concrete may be hastened by heat supplied by radiators, or preferably by a fan system.

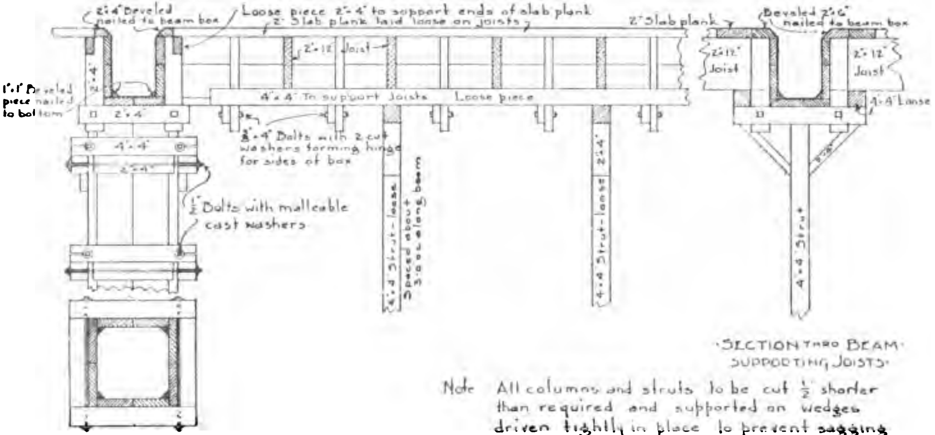
The general system of forming is that the joists are supported upon the beams by means of a loose piece of 4 x 4, which may be removed, thus removing the entire support of the joists, which are not nailed in place, and they may be immediately taken down, together with the 2″ plank used for the slab. After the removal of the joists and the slab, the forms for the beams are removed by opening them away from the beam, the sides swinging on the bolts which act as hinges at the lower ends of the battens.

Column forms are built entirely of 2″ stuff having each side held together by battens. Binders for the column forms consist of 4 x 4 pine slotted at the ends to receive ½″ bolts having malleable cast washers. It will be noticed that the beam supporting the joists is slightly different from the beam parallel to the joists.

The table on page 102 indicates the board measure to be used for slabs, beams and columns, slabs being given per square foot, beams of the two types being given per lineal foot, and columns being given by the lineal foot. The sizes of the beams below the slab are noted in inches together with the number of feet board measure required to build the forms. Columns for various sizes are given together with the board measure required to build the forms, the forms including all battens, binders, etc. Beams and columns of other sizes than those given may be determined by interpolation. All struts supporting the beams are included in the board measure here given.

Construction of Forms.

·DETAILS OF COLLAPSIBLE FORMS FOR SLABS. BEAMS AND COLUMNS·


2"×4" Beveled nailed to beam box
Loose piece 2"×4" to support ends of slab plank
2" Slab plank laid loose on joists
2"×12" Joist
4"×4" To support Joists
Loose piece
2"×4"
2"×4"
1"×1" Beveled piece nailed to bottom
4"×4"
2"×4"
⅜"×4" Bolts with 2 cut washers forming hinge for sides of box
½" Bolts with malleable cast washers
4"×4" Strut-loose
Spaced about 3'-0" along beam
2"×4"
4"×4" Strut-loose
2" Slab plank
Beveled 2"×6" nailed to beam box
2"×12" Joist
2"×12" Joist
4"×4" Loose
2"×4"
4"×4" Strut

·SECTION THRO COLUMN·

·SECTION THRO BEAM SUPPORTING JOISTS·

Note: All columns and struts to be cut ½" shorter than required and supported on wedges driven tightly in place to prevent sagging of beams".

Lumber for Forms.

LUMBER REQUIRED TO FORM SLABS BEAMS AND COLUMNS ACCORDING TO DETAIL

SLABS - PER SQUARE FOOT.

PLANK AND JOISTS REQD 3 B.M.*

BEAMS PER LINEAL FOOT

·BEAMS SUPPORTING JOISTS AND INCLUDING STRUTS·

FOR BEAM BELOW SLAB	10"×15"	12"×21"	14"×27"
MATERIAL REQUIRED	21 B.M.*	24 B.M.*	27 B.M.*

BEAMS PARALLEL TO JOISTS AND INCLUDING STRUTS

FOR BEAM BELOW SLAB	10"×15"	12"×21"	14"×27"
MATERIAL REQUIRED	19 B.M.*	22 B.M.*	25 B.M.*

COLUMNS PER LINEAL FOOT

INCLUDING BINDERS AND BATTENS

SIZE OF COLUMN	12"×12"	16"×16"	20"×20"	24"×24"
MATERIAL REQUIRED	15 B.M.*	21 B.M.*	27 B.M.*	33 B.M.*

* B.M. indicates Board Measure.

Proportions of Materials in Concrete.

The tables from pages 100 to 103 are taken from experiments made at the University of Cornell, and it has been found by experience that the proportions of the various materials required to make one cubic yard of concrete agree fairly well with the quantities given in these tables. They are not given as being absolutely correct, but as the best available information on the subject and entirely satisfactory for estimating purposes. For use in reinforced concrete the table for gravel, given upon page 100, and the one with the hazelnut stone, upon page 101, should be used. Stone of 2″ size is rarely used in reinforced concrete.

There should be an abundance of water mixed with the concrete used for reinforcement, as it gives a tougher mixture when fully set and is more economical in placing; it comes in closer contact with the steel and the cement is more likely to thoroughly coat every surface than where the concrete is so dry as to require tamping.

For reinforced concrete work in which the extreme fibre in bending is strained to 500 pounds per square inch or direct compression is figured at 350 pounds per square inch as in these tables the proportions of one part of cement, to two parts of sand, to four parts of hazelnuf stone or gravel are recommended.

Gravel Concrete.

AMOUNTS OF CEMENT · SAND AND STONE · REQUIRED FOR CONCRETE MIXTURES ·

CONCRETE WITH GRAVEL ¾" AND UNDER

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD ·		
CEMENT	SAND	GRAVEL	CEMENT BBLS	SAND CU. YDS	GRAVEL CU. YDS
1	1.0	2.5	2.10	0.32	0.80
1	1.0	3.0	1.89	0.29	0.86
1	1.0	3.5	1.71	0.26	0.91
1	1.0	4.0	1.55	0.24	0.94
1	1.5	3.0	1.71	0.39	0.78
1	1.5	3.5	1.57	0.36	0.83
1	1.5	4.0	1.46	0.33	0.88
1	1.5	4.5	1.34	0.31	0.91
1	1.5	5.0	1.24	0.28	0.94
1	2.0	3.5	1.44	0.44	0.77
1	2.0	4.0	1.34	0.41	0.81
1	2.0	4.5	1.26	0.38	0.86
1	2.0	5.0	1.17	0.36	0.89
1	2.0	6.0	1 03	0.31	0.94
1	2.5	4.0	1.24	0.47	0.75
1	2.5	4.5	1.16	0.44	0.80
1	2.5	5.0	1.10	0.42	0.83
1	2.5	5.5	1.03	0.39	0.86
1	2.5	6.0	0.98	0.37	0.89
1	2.5	7.0	0.88	0.33	0.93
1	3.0	5.0	1 03	0 47	0.78
1	3.0	5.5	0 97	0.44	0.81
1	3.0	6.0	0.92	0.42	0.84
1	3.0	6.5	0.88	0.40	0.87
1	3 0	7.0	0.84	0.38	0.89
1	3.0	7.5	0.80	0 37	0.91
1	3.0	8.0	0.76	0.35	0.93
1	3.5	6.0	0.88	0.46	0.80
1	3.5	6.5	0.83	0.44	0.82
1	3.5	7.0	0.80	0.43	0.85
1	3.5	7.5	0.76	0.41	0.87
1	3.5	8 0	0.73	0.39	0.89
1	3.5	8.5	0.71	0.38	0.91
1	3.5	9.0	0.68	0.36	0 92
1	4.0	7.0	0.77	0.47	0.81
1	4 0	7.5	0.73	0 44	0.83
1	4.0	8.0	0.71	0.43	0.86
1	4.0	8 5	0.68	0.42	0.88
1	4.0	9 0	0.65	0.40	0.89
1	4.0	9 5	0.63	0 38	0.91
1	4.0	10.0	0.61	0 37	0.93
1	5.0	10.0	0.57	0.43	0.87
1	5 0	12.0	0.51	0.38	0.92
1	6.0	12.0	0 48	0.44	0 88
1	6 0	14.0	0 43	0.40	0.92
1	7 0	14.0	0.42	0.44	0.88
1	7 0	16.0	0.38	0 40	0.92

Hazelnut Stone Concrete.

AMOUNTS OF CEMENT· SAND AND STONE REQUIRED FOR CONCRETE MIXTURES·

CONCRETE WITH "HAZELNUT" STONE·

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD·		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU. YDS	STONE CU. YDS
1	1.0	2.0	2.57	0.39	0.78
1	1.0	2.5	2.29	0.35	0.86
1	1.0	3.0	2.06	0.31	0.94
1	1.0	3.5	1.84	0.28	0.98
1	1.5	2.5	2.05	0.47	0.78
1	1.5	3.0	1.85	0.42	0.84
1	1.5	3.5	1.72	0.39	0.91
1	1.5	4.0	1.57	0.36	0.96
1	1.5	4.5	1.43	0.33	0.98
1	2.0	3.0	1.70	0.52	0.77
1	2.0	3.5	1.57	0.48	0.83
1	2.0	4.0	1.46	0.44	0.89
1	2.0	4.5	1.36	0.42	0.93
1	2.0	5.0	1.27	0.39	0.97
1	2.5	3.5	1.45	0.55	0.77
1	2.5	4.0	1.35	0.52	0.82
1	2.5	4.5	1.27	0.48	0.87
1	2.5	5.0	1.19	0.46	0.91
1	2.5	5.5	1.13	0.43	0.94
1	2.5	6.0	1.07	0.41	0.97
1	3.0	4.0	1.26	0.58	0.77
1	3.0	4.5	1.18	0.54	0.81
1	3.0	5.0	1.11	0.51	0.85
1	3.0	5.5	1.06	0.48	0.89
1	3.0	6.0	1.01	0.46	0.92
1	3.0	6.5	0.96	0.44	0.95
1	3.0	7.0	0.91	0.42	0.97
1	3.5	5.0	1.05	0.56	0.80
1	3.5	5.5	1.00	0.53	0.84
1	3.5	6.0	0.95	0.50	0.87
1	3.5	6.5	0.92	0.49	0.91
1	3.5	7.0	0.87	0.47	0.93
1	3.5	7.5	0.84	0.45	0.96
1	3.5	8.0	0.80	0.42	0.97
1	4.0	6.0	0.90	0.55	0.82
1	4.0	6.5	0.87	0.53	0.85
1	4.0	7.0	0.83	0.51	0.89
1	4.0	7.5	0.80	0.49	0.91
1	4.0	8.0	0.77	0.47	0.93
1	4.0	8.5	0.74	0.45	0.95
1	4.0	9.0	0.71	0.43	0.97
1	5.0	9.0	0.66	0.50	0.90
1	5.0	10.0	0.62	0.47	0.95
1	6.0	11.0	0.55	0.51	0.93
1	6.0	12.0	0.52	0.48	0.95
1	7.0	13.0	0.47	0.50	0.93
1	7.0	14.0	0.45	0.48	0.96

Gravel Concrete.

AMOUNTS OF CEMENT · SAND AND STONE · REQUIRED FOR CONCRETE MIXTURES ·

CONCRETE WITH GRAVEL ¾" AND UNDER

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD ·		
CEMENT	SAND	GRAVEL	CEMENT BBLS	SAND CU. YDS	GRAVEL CU. YDS
1	1.0	2.5	2.10	0.32	0.80
1	1.0	3.0	1.89	0.29	0.86
1	1.0	3.5	1.71	0.26	0.91
1	1.0	4.0	1.55	0.24	0.94
1	1.5	3.0	1.71	0.39	0.78
1	1.5	3.5	1.57	0.36	0.83
1	1.5	4.0	1.46	0.33	0.88
1	1.5	4.5	1.34	0.31	0.91
1	1.5	5.0	1.24	0.28	0.94
1	2.0	3.5	1.44	0.44	0.77
1	2.0	4.0	1.34	0.41	0.81
1	2.0	4.5	1.26	0.38	0.86
1	2.0	5.0	1.17	0.36	0.89
1	2.0	6.0	1 03	0.31	0.94
1	2.5	4.0	1.24	0.47	0.75
1	2.5	4.5	1.16	0.44	0.80
1	2.5	5.0	1.10	0.42	0.83
1	2.5	5.5	1.03	0.39	0.86
1	2.5	6.0	0.98	0.37	0.89
1	2.5	7.0	0 88	0.33	0.93
1	3.0	5.0	1.03	0 47	0.78
1	3.0	5.5	0 97	0.44	0.81
1	3.0	6.0	0.92	0.42	0.84
1	3.0	6.5	0.88	0.40	0.87
1	3 0	7.0	0.84	0.38	0.89
1	3.0	7.5	0.80	0 37	0.91
1	3.0	8.0	0.76	0.35	0.93
1	3.5	6.0	0.88	0.46	0.80
1	3.5	6.5	0.83	0.44	0.82
1	3.5	7.0	0.80	0.43	0.85
1	3.5	7.5	0.76	0.41	0.87
1	3.5	8 0	0.73	0.39	0.89
1	3.5	8.5	0.71	0.38	0.91
1	3.5	9.0	0.68	0.36	0 92
1	4.0	7.0	0.77	0.47	0.81
1	4 0	7.5	0.73	0 44	0.83
1	4.0	8.0	0.71	0.43	0.86
1	4.0	8 5	0.68	0.42	0.88
1	4.0	9 0	0.65	0.40	0.89
1	4.0	9 5	0.63	0 38	0.91
1	4.0	10.0	0.61	0 37	0.93
1	5.0	10.0	0.57	0.43	0.87
1	5 0	12.0	0.51	0.38	0.92
1	6.0	12.0	0 48	0.44	0 88
1	6 0	14.0	0 43	0.40	0.92
1	7 0	14.0	0.42	0.44	0.88
1	7 0	16.0	0.38	0 40	0.92

Hazelnut Stone Concrete.

AMOUNTS OF CEMENT· SAND AND STONE REQUIRED FOR CONCRETE MIXTURES·

CONCRETE WITH "HAZELNUT" STONE·

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD·		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU.YDS	STONE CU.YDS
1	1.0	2.0	2.57	0.39	0.78
1	1.0	2.5	2.29	0.35	0.86
1	1.0	3.0	2.06	0.31	0.94
1	1.0	3.5	1.84	0.28	0.98
1	1.5	2.5	2.05	0.47	0.78
1	1.5	3.0	1.85	0.42	0.84
1	1.5	3.5	1.72	0.39	0.91
1	1.5	4.0	1.57	0.36	0.96
1	1.5	4.5	1.43	0.33	0.98
1	2.0	3.0	1.70	0.52	0.77
1	2.0	3.5	1.57	0.48	0.83
1	2.0	4.0	1.46	0.44	0.89
1	2.0	4.5	1.36	0.42	0.93
1	2.0	5.0	1.27	0.39	0.97
1	2.5	3.5	1.45	0.55	0.77
1	2.5	4.0	1.35	0.52	0.82
1	2.5	4.5	1.27	0.48	0.87
1	2.5	5.0	1.19	0.46	0.91
1	2.5	5.5	1.13	0.43	0.94
1	2.5	6.0	1.07	0.41	0.97
1	3.0	4.0	1.26	0.58	0.77
1	3.0	4.5	1.18	0.54	0.81
1	3.0	5.0	1.11	0.51	0.85
1	3.0	5.5	1.06	0.48	0.89
1	3.0	6.0	1.01	0.46	0.92
1	3.0	6.5	0.96	0.44	0.95
1	3.0	7.0	0.91	0.42	0.97
1	3.5	5.0	1.05	0.56	0.80
1	3.5	5.5	1.00	0.53	0.84
1	3.5	6.0	0.95	0.50	0.87
1	3.5	6.5	0.92	0.49	0.91
1	3.5	7.0	0.87	0.47	0.93
1	3.5	7.5	0.84	0.45	0.96
1	3.5	8.0	0.80	0.42	0.97
1	4.0	6.0	0.90	0.55	0.82
1	4.0	6.5	0.87	0.53	0.85
1	4.0	7.0	0.83	0.51	0.89
1	4.0	7.5	0.80	0.49	0.91
1	4.0	8.0	0.77	0.47	0.93
1	4.0	8.5	0.74	0.45	0.95
1	4.0	9.0	0.71	0.43	0.97
1	5.0	9.0	0.66	0.50	0.90
1	5.0	10.0	0.62	0.47	0.95
1	6.0	11.0	0.55	0.51	0.93
1	6.0	12.0	0.52	0.48	0.95
1	7.0	13.0	0.47	0.50	0.93
1	7.0	14.0	0.45	0.48	0.96

Graded Stone Concrete.

AMOUNTS OF CEMENT-SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

CONCRETE WITH STONE 2½" AND UNDER

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	GRAVEL	CEMENT BBLS.	SAND CU. YDS.	STONE CU. YDS.
1	1.0	2.0	2.63	0.40	0.80
1	1.0	2.5	2.34	0.36	0.89
1	1.0	3.0	2.10	0.32	0.96
1	1.0	3.5	1.88	0.29	1.00
1	1.5	2.5	2.08	0.48	0.80
1	1.5	3.0	1.90	0.43	0.87
1	1.5	3.5	1.74	0.40	0.93
1	1.5	4.0	1.61	0.37	0.98
1	1.5	4.5	1.46	0.33	1.00
1	2.0	3.0	1.73	0.53	0.79
1	2.0	3.5	1.61	0.49	0.85
1	2.0	4.0	1.48	0.45	0.90
1	2.0	4.5	1.38	0.42	0.95
1	2.0	5.0	1.29	0.39	0.98
1	2.5	3.5	1.48	0.56	0.79
1	2.5	4.0	1.38	0.53	0.84
1	2.5	4.5	1.29	0.49	0.88
1	2.5	5.0	1.21	0.46	0.92
1	2.5	5.5	1.15	0.44	0.96
1	2.5	6.0	1.07	0.41	0.98
1	3.0	4.0	1.28	0.58	0.78
1	3.0	4.5	1.20	0.55	0.82
1	3.0	5.0	1.14	0.52	0.87
1	3.0	5.5	1.07	0.49	0.90
1	3.0	6.0	1.02	0.47	0.93
1	3.0	6.5	0.98	0.44	0.96
1	3.0	7.0	0.92	0.42	0.98
1	3.5	5.0	1.07	0.57	0.82
1	3.5	5.5	1.02	0.54	0.85
1	3.5	6.0	0.97	0.51	0.89
1	3.5	6.5	0.93	0.49	0.92
1	3.5	7.0	0.89	0.47	0.95
1	3.5	7.5	0.86	0.45	0.98
1					
1	4.0	6.0	0.92	0.56	0.84
1	4.0	6.5	0.88	0.53	0.87
1	4.0	7.0	0.84	0.51	0.90
1	4.0	7.5	0.81	0.50	0.93
1	4.0	8.0	0.78	0.48	0.95
1	4.0	8.5	0.76	0.46	0.98
1	5.0	9.0	0.67	0.52	0.93
1	5.0	10.0	0.63	0.48	0.96
1	6.0	11.0	0.56	0.52	0.94
1	6.0	12.0	0.54	0.49	0.98
1	7.0	13.0	0.48	0.51	0.95
1	7.0	14.0	0.46	0.49	0.98

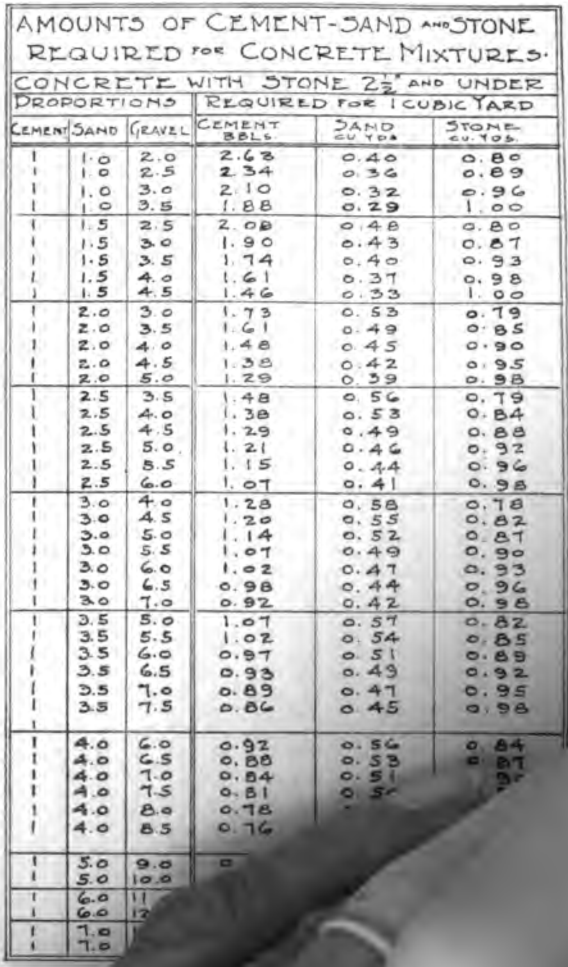
Two and One-half Inch Stone Concrete,

AMOUNTS OF CEMENT - SAND AND STONE · REQUIRED FOR CONCRETE MIXTURES

CONCRETE WITH STONE 2½"

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU YDS	STONE CU YDS
1	1.0	2.0	2.72	0.41	0.83
1	1.0	2.5	2.41	0.37	0.92
1	1.0	3.0	2.16	0.33	0.98
1					
1	1.5	2.5	2.16	0.49	0.82
1	1.5	3.0	1.96	0.45	0.89
1	1.5	3.5	1.79	0.41	0.96
1	1.5	4.0	1.64	0.38	1.00
1	2.0	3.0	1.78	0.54	0.81
1	2.0	3.5	1.66	0.50	0.88
1	2.0	4.0	1.53	0.47	0.93
1	2.0	4.5	1.43	0.43	0.98
1	2.5	3.5	1.51	0.58	0.81
1	2.5	4.0	1.42	0.54	0.87
1	2.5	4.5	1.33	0.51	0.91
1	2.5	5.0	1.26	0.48	0.96
1	2.5	5.5	1.18	0.44	0.99
1	3.0	4.0	1.32	0.60	0.80
1	3.0	4.5	1.24	0.57	0.85
1	3.0	5.0	1.17	0.54	0.89
1	3.0	5.5	1.11	0.51	0.93
1	3.0	6.0	1.06	0.48	0.97
1	3.5	5.0	1.11	0.59	0.85
1	3.5	5.5	1.06	0.56	0.89
1	3.5	6.0	1.00	0.53	0.92
1	3.5	6.5	0.96	0.51	0.95
1	3.5	7.0	0.91	0.49	0.98
1	4.0	6.0	0.95	0.58	0.87
1	4.0	6.5	0.91	0.55	0.90
1	4.0	7.0	0.87	0.53	0.93
1	4.0	7.5	0.84	0.51	0.96
1	4.0	8.0	0.81	0.49	0.98
1	5.0	8.0	0.74	0.57	0.91
1	5.0	9.0	0.70	0.53	0.96
1	6.0	9.0	0.65	0.59	0.89
1	6.0	10.0	0.62	0.56	0.93
1	7.0	11.0	0.54	0.51	0.91
1	7.0	12.0	0.52	0.55	0.95

Graded Stone Concrete.



AMOUNTS OF CEMENT-SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

CONCRETE WITH STONE 2½" AND UNDER

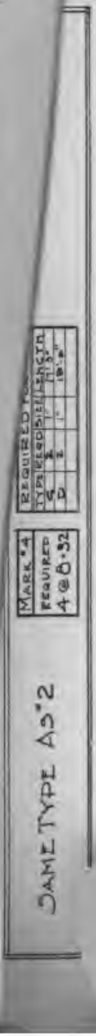
PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	GRAVEL	CEMENT BBLS.	SAND CU. YDS.	STONE CU. YDS.
1	1.0	2.0	2.68	0.40	0.80
1	1.0	2.5	2.34	0.36	0.89
1	1.0	3.0	2.10	0.32	0.96
1	1.0	3.5	1.88	0.29	1.00
1	1.5	2.5	2.08	0.48	0.80
1	1.5	3.0	1.90	0.43	0.87
1	1.5	3.5	1.74	0.40	0.93
1	1.5	4.0	1.61	0.37	0.98
1	1.5	4.5	1.46	0.33	1.00
1	2.0	3.0	1.73	0.53	0.79
1	2.0	3.5	1.61	0.49	0.85
1	2.0	4.0	1.48	0.45	0.90
1	2.0	4.5	1.38	0.42	0.95
1	2.0	5.0	1.29	0.39	0.98
1	2.5	3.5	1.48	0.56	0.79
1	2.5	4.0	1.38	0.53	0.84
1	2.5	4.5	1.29	0.49	0.88
1	2.5	5.0	1.21	0.46	0.92
1	2.5	5.5	1.15	0.44	0.96
1	2.5	6.0	1.07	0.41	0.98
1	3.0	4.0	1.28	0.58	0.78
1	3.0	4.5	1.20	0.55	0.82
1	3.0	5.0	1.14	0.52	0.87
1	3.0	5.5	1.07	0.49	0.90
1	3.0	6.0	1.02	0.47	0.93
1	3.0	6.5	0.98	0.44	0.96
1	3.0	7.0	0.92	0.42	0.98
1	3.5	5.0	1.07	0.57	0.82
1	3.5	5.5	1.02	0.54	0.85
1	3.5	6.0	0.97	0.51	0.89
1	3.5	6.5	0.93	0.49	0.92
1	3.5	7.0	0.89	0.47	0.95
1	3.5	7.5	0.86	0.45	0.98
1	4.0	6.0	0.92	0.56	0.84
1	4.0	6.5	0.88	0.53	0.87
1	4.0	7.0	0.84	0.51	[illegible]
1	4.0	7.5	0.81	[illegible]	[illegible]
1	4.0	8.0	0.78	[illegible]	[illegible]
1	4.0	8.5	0.76	[illegible]	[illegible]
1	5.0	9.0	[illegible]	[illegible]	[illegible]
1	5.0	10.0	[illegible]	[illegible]	[illegible]
1	6.0	[illegible]	[illegible]	[illegible]	[illegible]
1	6.0	[illegible]	[illegible]	[illegible]	[illegible]
1	7.0	[illegible]	[illegible]	[illegible]	[illegible]
1	7.0	[illegible]	[illegible]	[illegible]	[illegible]

Two and One-half Inch Stone Concrete.

AMOUNTS OF CEMENT - SAND AND STONE REQUIRED FOR CONCRETE MIXTURES

CONCRETE WITH STONE 2½"

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU. YDS	STONE CU. YDS
1	1.0	2.0	2.72	0.41	0.83
1	1.0	2.5	2.41	0.37	0.92
1	1.0	3.0	2.16	0.33	0.98
1	1.5	2.5	2.16	0.49	0.83
1	1.5	3.0	1.96	0.45	0.85
1	1.5	3.5	1.79	0.41	0.96
1	1.5	4.0	1.64	0.38	1.00
1	2.0	3.0	1.78	0.54	0.81
1	2.0	3.5	1.66	0.50	0.88
1	2.0	4.0	1.53	0.47	0.93
1	2.0	4.5	1.43	0.43	0.98
1	2.5	3.5	1.51	0.56	0.81
1	2.5	4.0	1.42	0.54	0.87
1	2.5	4.5	1.33	0.51	0.91
1	2.5	5.0	1.26	0.48	0.96
1	2.5	5.5	1.18	0.44	0.99
1	3.0	4.0	1.32	0.60	0.80
1	3.0	4.5	1.24	0.57	0.85
1	3.0	5.0	1.17	0.54	0.89
1	3.0	5.5	1.11	0.51	0.93
1	3.0	6.0	1.06	0.48	0.97
1	3.5	5.0	1.11	0.59	0.83
1	3.5	5.5	1.06	0.56	0.89
1	3.5	6.0	[illegible]	[illegible]	0.92
1	3.5	6.5	[illegible]	[illegible]	0.95
[illegible]	[illegible]	7.0	[illegible]	[illegible]	0.98
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.87
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.90
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.93
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.96
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.98
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.91
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.96
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.89
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.93
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.91



Gravel Concrete.

AMOUNTS OF CEMENT · SAND AND STONE · REQUIRED FOR CONCRETE MIXTURES ·

CONCRETE WITH GRAVEL 2" AND UNDER

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD ·		
CEMENT	SAND	GRAVEL	CEMENT BBLS	SAND CU. YDS	GRAVEL CU. YDS
1	1.0	2.5	2.10	0.32	0.80
1	1.0	3.0	1.89	0.29	0.86
1	1.0	3.5	1.71	0.26	0.91
1	1.0	4.0	1.55	0.24	0.94
1	1.5	3.0	1.71	0.39	0.78
1	1.5	3.5	1.57	0.36	0.83
1	1.5	4.0	1.46	0.33	0.88
1	1.5	4.5	1.34	0.31	0.91
1	1.5	5.0	1.24	0.28	0.94
1	2.0	3.5	1.44	0.44	0.77
1	2.0	4.0	1.34	0.41	0.81
1	2.0	4.5	1.26	0.38	0.86
1	2.0	5.0	1.17	0.36	0.89
1	2.0	6.0	1 03	0.31	0.94
1	2.5	4.0	1.24	0.47	0.75
1	2.5	4.5	1.16	0.44	0.80
1	2.5	5.0	1.10	0.42	0.83
1	2.5	5.5	1.03	0.39	0.86
1	2.5	6.0	0.98	0.37	0.89
1	2.5	7.0	0 88	0.33	0.93
1	3.0	5.0	1 03	0 47	0.78
1	3.0	5.5	0 97	0.44	0.81
1	3.0	6.0	0.92	0.42	0.84
1	3.0	6.5	0.88	0.40	0.87
1	3 0	7.0	0.84	0.38	0.89
1	3.0	7.5	0.80	0 37	0.91
1	3 0	8.0	0.76	0.35	0.93
1	3.5	6.0	0.88	0.46	0.80
1	3.5	6.5	0.83	0.44	0.82
1	3.5	7.0	0.80	0.43	0.85
1	3.5	7.5	0.76	0.41	0.87
1	3.5	8 0	0.73	0.39	0.89
1	3.5	8.5	0.71	0.38	0.91
1	3.5	9.0	0.68	0.36	0 92
1	4.0	7.0	0.77	0.47	0.81
1	4 0	7.5	0.73	0 44	0.83
1	4 0	8.0	0.71	0.43	0.86
1	4.0	8 5	0.68	0.42	0.88
1	4.0	9 0	0.65	0.40	0.89
1	4.0	9 5	0.63	0 38	0.91
1	4.0	10.0	0.61	0 37	0.93
1	5.0	10.0	0.57	0.43	0 87
1	5 0	12.0	0.51	0.38	0.92
1	6.0	12.0	0 48	0.44	0 88
1	6 0	14.0	0 43	0.40	0.92
1	7 0	14.0	0.42	0.44	0.88
1	7 0	16.0	0.38	0 40	0.92

Hazelnut Stone Concrete.

AMOUNTS OF CEMENT·SAND AND STONE REQUIRED FOR CONCRETE MIXTURES·

CONCRETE WITH "HAZELNUT" STONE·

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD·		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU. YDS	STONE CU. YDS
1	1.0	2.0	2.57	0.39	0.78
1	1.0	2.5	2.29	0.35	0.86
1	1.0	3.0	2.06	0.31	0.94
1	1.0	3.5	1.84	0.28	0.98
1	1.5	2.5	2.05	0.47	0.78
1	1.5	3.0	1.85	0.42	0.84
1	1.5	3.5	1.72	0.39	0.91
1	1.5	4.0	1.57	0.36	0.96
1	1.5	4.5	1.43	0.33	0.98
1	2.0	3.0	1.70	0.52	0.77
1	2 0	3.5	1.57	0.48	0.83
1	2.0	4.0	1.46	0.44	0.89
1	2.0	4.5	1.36	0.42	0.93
1	2.0	5.0	1.27	0.39	0.97
1	2 5	3.5	1.45	0.55	0.77
1	2.5	4.0	1.35	0.52	0.82
1	2.5	4.5	1.27	0.48	0.87
1	2.5	5.0	1.19	0.46	0.91
1	2.5	5.5	1.13	0.43	0.94
1	2.5	6.0	1.07	0.41	0.97
1	3.0	4.0	1.26	0.58	0.77
1	3.0	4.5	1.18	0.54	0.81
1	3 0	5.0	1.11	0.51	0.85
1	3.0	5.5	1.06	0.48	0.89
1	3.0	6.0	1.01	0.46	0.92
1	3 0	6.5	0.96	0.44	0.95
1	3.0	7.0	0.91	0.42	0.97
1	3.5	5.0	1.05	0.56	0.80
1	3.5	5.5	1.00	0.53	0.84
1	3.5	6.0	0.95	0.50	0.87
1	3.5	6.5	0.92	0.49	0.91
1	3.5	7.0	0.87	0.47	0.93
1	3.5	7.5	0.84	0.45	0.96
1	3.5	8.0	0.80	0.42	0.97
1	4.0	6.0	0.90	0.55	0.82
1	4.0	6.5	0.87	0.53	0.85
1	4.0	7.0	0.83	0.51	0.89
1	4.0	7.5	0.80	0.49	0.91
1	4.0	8.0	0.77	0.47	0.93
1	4.0	8.5	0.74	0.45	0.95
1	4.0	9.0	0.71	0.43	0.97
1	5.0	9.0	0.66	0.50	0.90
1	5.0	10.0	0.62	0.47	0.95
1	6.0	11.0	0.55	0.51	0.93
1	6.0	12.0	0.52	0.48	0.95
1	7.0	13.0	0.47	0.50	0.93
1	7.0	14.0	0.45	0.48	0.96

Graded Stone Concrete.

AMOUNTS OF CEMENT-SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

CONCRETE WITH STONE 2½" AND UNDER

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	GRAVEL	CEMENT BBLS.	SAND CU. YDS.	STONE CU. YDS.
1	1.0	2.0	2.63	0.40	0.80
1	1.0	2.5	2.34	0.36	0.89
1	1.0	3.0	2.10	0.32	0.96
1	1.0	3.5	1.88	0.29	1.00
1	1.5	2.5	2.08	0.48	0.80
1	1.5	3.0	1.90	0.43	0.87
1	1.5	3.5	1.74	0.40	0.93
1	1.5	4.0	1.61	0.37	0.98
1	1.5	4.5	1.46	0.33	1.00
1	2.0	3.0	1.73	0.53	0.79
1	2.0	3.5	1.61	0.49	0.85
1	2.0	4.0	1.48	0.45	0.90
1	2.0	4.5	1.38	0.42	0.95
1	2.0	5.0	1.29	0.39	0.98
1	2.5	3.5	1.48	0.56	0.79
1	2.5	4.0	1.38	0.53	0.84
1	2.5	4.5	1.29	0.49	0.88
1	2.5	5.0	1.21	0.46	0.92
1	2.5	5.5	1.15	0.44	0.96
1	2.5	6.0	1.07	0.41	0.98
1	3.0	4.0	1.28	0.58	0.78
1	3.0	4.5	1.20	0.55	0.82
1	3.0	5.0	1.14	0.52	0.87
1	3.0	5.5	1.07	0.49	0.90
1	3.0	6.0	1.02	0.47	0.93
1	3.0	6.5	0.98	0.44	0.96
1	3.0	7.0	0.92	0.42	0.98
1	3.5	5.0	1.07	0.57	0.82
1	3.5	5.5	1.02	0.54	0.85
1	3.5	6.0	0.97	0.51	0.89
1	3.5	6.5	0.93	0.49	0.92
1	3.5	7.0	0.89	0.47	0.95
1	3.5	7.5	0.86	0.45	0.98
1	4.0	6.0	0.92	0.56	0.84
1	4.0	6.5	0.88	0.53	0.87
1	4.0	7.0	0.84	0.51	0.90
1	4.0	7.5	0.81	0.50	0.93
1	4.0	8.0	0.78	0.48	0.95
1	4.0	8.5	0.76	0.46	0.98
1	5.0	9.0	0.67	0.52	0.93
1	5.0	10.0	0.63	0.48	0.96
1	6.0	11.0	0.56	0.52	0.94
1	6.0	12.0	0.54	0.49	0.98
1	7.0	13.0	0.48	0.51	0.95
1	7.0	14.0	0.46	0.49	0.98

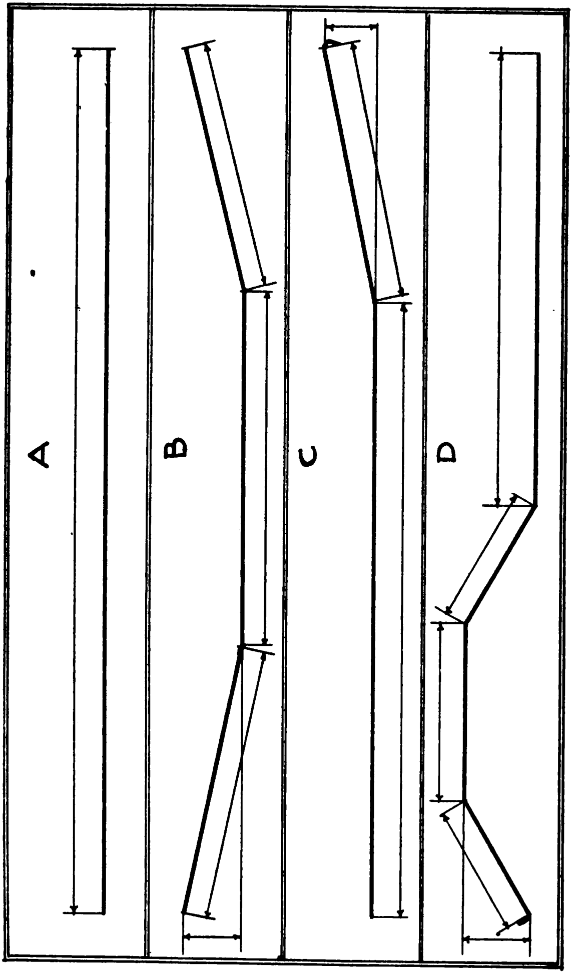
Two and One-half Inch Stone Concrete.

AMOUNTS OF CEMENT - SAND AND STONE REQUIRED FOR CONCRETE MIXTURES

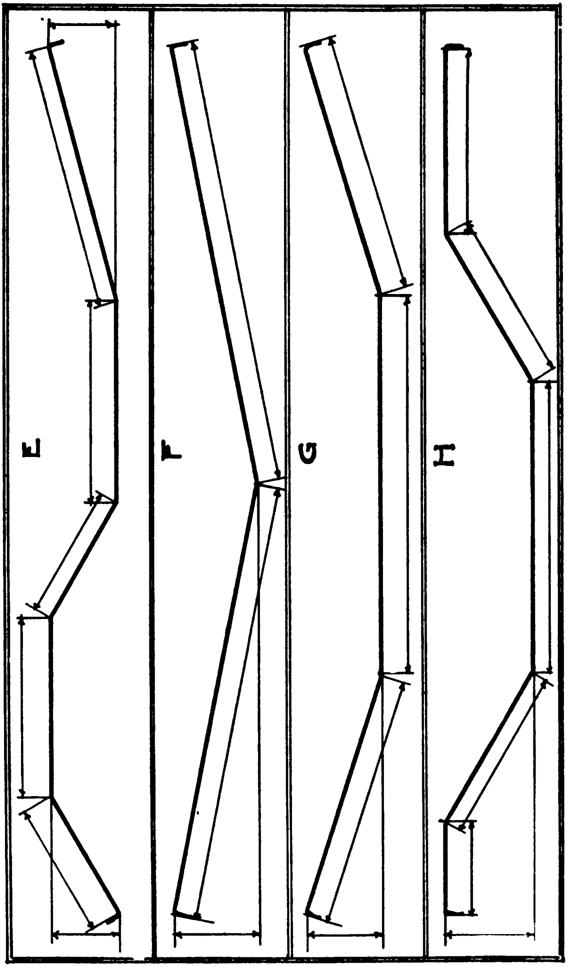
CONCRETE WITH STONE 2½"

PROPORTIONS			REQUIRED FOR 1 CUBIC YARD		
CEMENT	SAND	STONE	CEMENT BBLS	SAND CU YDS	STONE CU YDS
1	1.0	2.0	2.72	0.41	0.83
1	1.0	2.5	2.41	0.37	0.92
1	1.0	3.0	2.16	0.33	0.98
1					
1	1.5	2.5	2.16	0.49	0.82
1	1.5	3.0	1.96	0.45	0.89
1	1.5	3.5	1.79	0.41	0.96
1	1.5	4.0	1.64	0.38	1.00
1	2.0	3.0	1.78	0.54	0.81
1	2.0	3.5	1.66	0.50	0.88
1	2.0	4.0	1.53	0.47	0.93
1	2.0	4.5	1.43	0.43	0.98
1	2.5	3.5	1.51	0.58	0.81
1	2.5	4.0	1.42	0.54	0.87
1	2.5	4.5	1.33	0.51	0.91
1	2.5	5.0	1.26	0.48	0.96
1	2.5	5.5	1.18	0.44	0.99
1	3.0	4.0	1.32	0.60	0.80
1	3.0	4.5	1.24	0.57	0.85
1	3.0	5.0	1.17	0.54	0.89
1	3.0	5.5	1.11	0.51	0.93
1	3.0	6.0	1.06	0.48	0.97
1	3.5	5.0	1.11	0.59	0.85
1	3.5	5.5	1.06	0.56	0.89
1	3.5	6.0	1.00	0.53	0.92
1	3.5	6.5	0.96	0.51	0.95
1	3.5	7.0	0.91	0.49	0.98
1	4.0	6.0	0.95	0.58	0.87
1	4.0	6.5	0.91	0.55	0.90
1	4.0	7.0	0.87	0.53	0.93
1	4.0	7.5	0.84	0.51	0.96
1	4.0	8.0	0.81	0.49	0.98
1	5.0	8.0	0.74	0.57	0.91
1	5.0	9.0	0.70	0.53	0.96
1	6.0	9.0	0.65	0.59	0.89
1	6.0	10.0	0.62	0.56	0.93
1	7.0	11.0	0.54	0.51	0.91
1	7.0	12.0	0.52	0.55	0.95

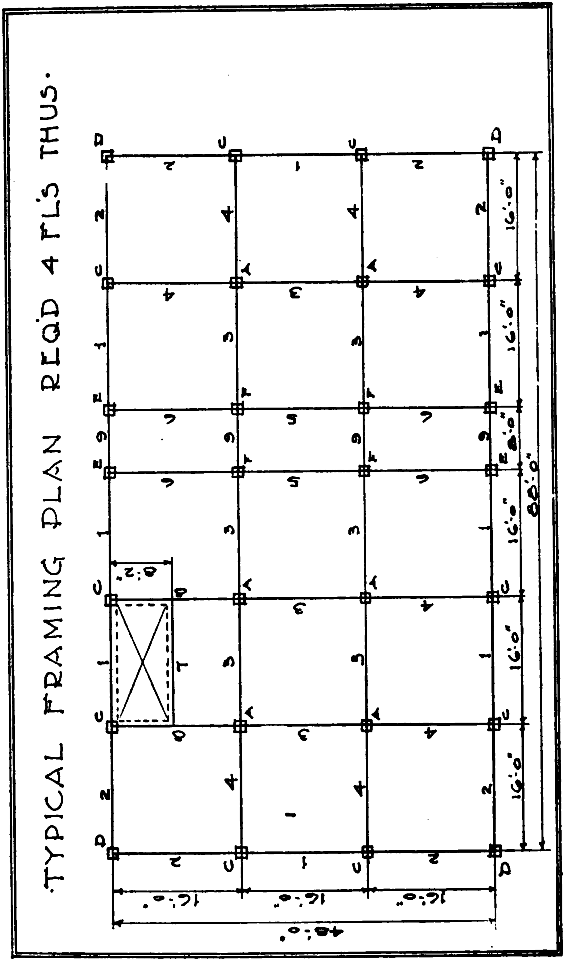
Standard Types of Rods.



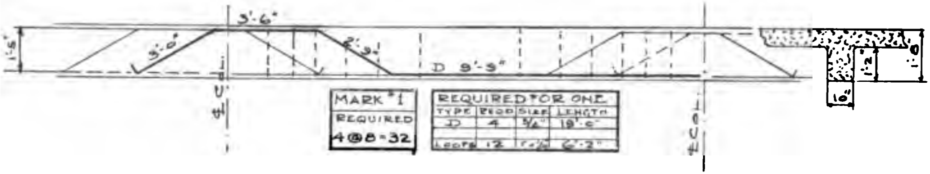
Standard Types of Rods.



A Typical Framing Plan.

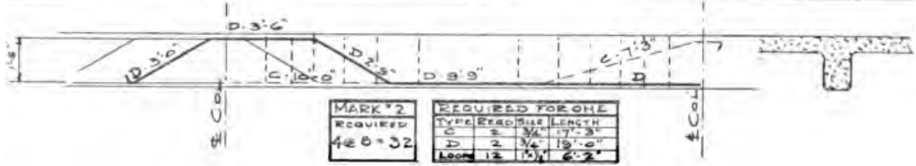


Shop Details for Beams.



MARK #1
REQUIRED
4 @ 8 = 32

REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
D	4	¾"	19'-0"
LOOPS	12	1¼"	6'-2"



MARK #2
REQUIRED
4 @ 8 = 32

REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
C	2	¾"	17'-3"
D	2	¾"	19'-0"
LOOPS	12	1¼"	6'-2"

SAME TYPE AS #1

MARK #3
REQUIRED
4 @ 9 = 36

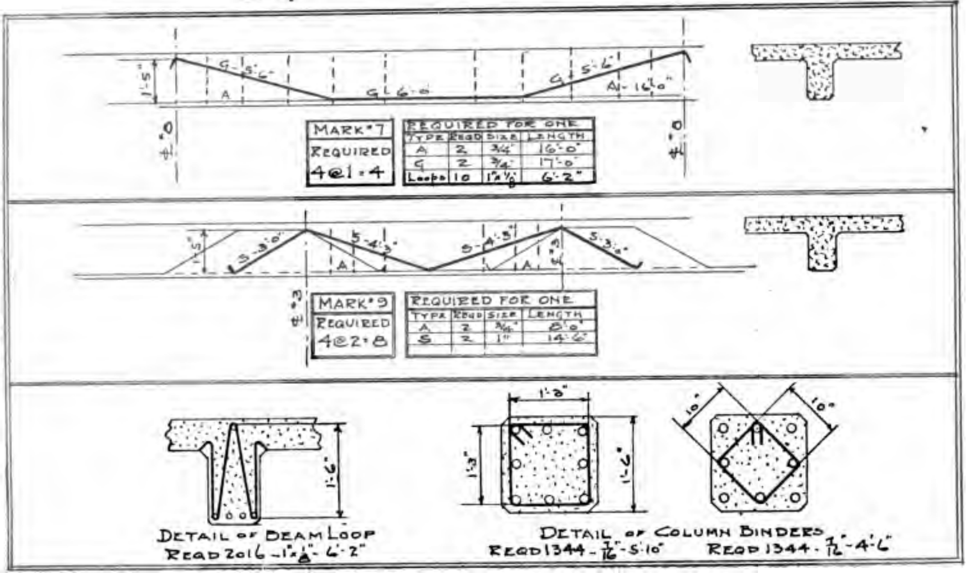
REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
D	4	1"	19'-0"
LOOPS	12	1¼"	6'-2"

SAME TYPE AS #2

MARK #4
REQUIRED
4 @ 8 = 32

REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
C	2	1"	17'-3"
D	2	1"	19'-0"

Shop Details for Beams and Columns.



MARK #7
REQUIRED
4@1'-4

REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
A	2	¾"	16'-0"
G	2	¾"	17'-0"
Loops	10	1"x⅛"	6'-2"

MARK #9
REQUIRED
4@2'-8

REQUIRED FOR ONE			
TYPE	REQD	SIZE	LENGTH
A	2	¾"	8'-0"
S	2	1"	14'-6"

DETAIL OF BEAM LOOP
REQD 2016 - 1"x⅛" - 6'-2"

DETAIL OF COLUMN BINDERS
REQD 1344 - 7/16" - 5'-10"   REQD 1344 - 7/16" - 4'-6"

[illegible]

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